R E P O R T R E S U M E S

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ILLUSTRATIONS OF RADIOISOTOPES--DEFINITIONS AND APPLICATIONS. ATOMIC ENERGY COMMISSION, OAK RIDGE, TENN.

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THIS PUBLICATION IS COMPOSED OF OVER 150 PAGES OF BLACK AND WHITE ILLUSTRATIONS DEALING WITH RADIOISOTOPES AND THEIR USES. THESE ILLUSTRATIONS CONSIST OF CHARTS, GRAPHS, AND PICTORIAL REPRESENTATIONS WHICH COULD BE PREPARED AS HANDOUTS, TRANSPARENCIES FOR OVERHEAD PROJECTION, OR WHICH COULD BE USED IN A NUMBER OF OTHER WAYS FOR PRESENTING SUCH TOPICS AS (1) DEFINITIONS OF RADIOISOTOPES, (2) ISOTOPE PRODUCTION AND AVAILABILITY, (3) ISOTOPE CHARACTERISTICS, AND (4) ISOTOPE APPLICATIONS. THE APPLICATIONS SECTION COMPRISES ABOUT THREE-FOURTHS OF THE DOCUMENT AND INCLUDES APPLICATIONS IN--(1) BIOLOGICAL AND MEDICAL RESEARCH, DIAGNOSIS, AND THERAPY, (2) AGRICULTURE, (3) THE PHYSICAL SCIENCES, AND (4) INDUSTRY. THIS DOCUMENT IS ALSO AVAILABLE AT NO COST FROM THE U.S. ATOMIC ENERGY COMMISSION, DIVISION OF TECHNICAL INFORMATION EXTENSION, EDUCATIONAL MATERIALS SECTION, P. O. BOX 62, OAK RIDGE, TENNESSEE 37831. (DS)

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Illustrations of RADIO-ISOTOPES

Definitions and Applications

United States Atomic Energy Commission
Division of Technical Information

SE 001 652

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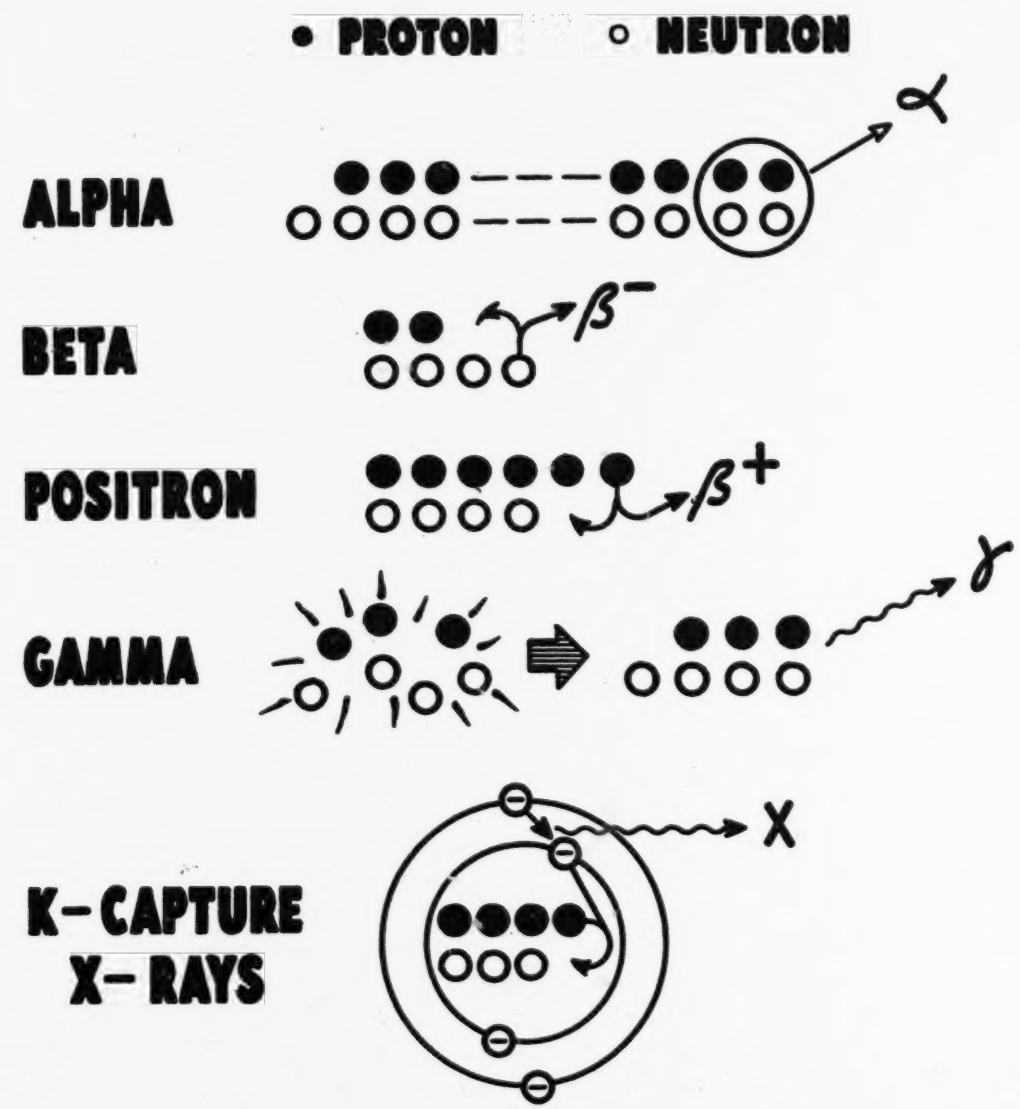
ISOTOPE ILLUSTRATIONS
DEFINITIONS OF RADIOISOTOPES

MECHANISMS OF RADIATION



USAEC-ID·208A

ISOTOPES
(NUCLEAR SPECIES OR NUCLIDES)

TOTAL NUMBER IDENTIFIED ~ 2000

STABLE

NUMBER IDENTIFIED	~	280
NUMBER AVAILABLE IN CONCENTRATED FORM	~	250

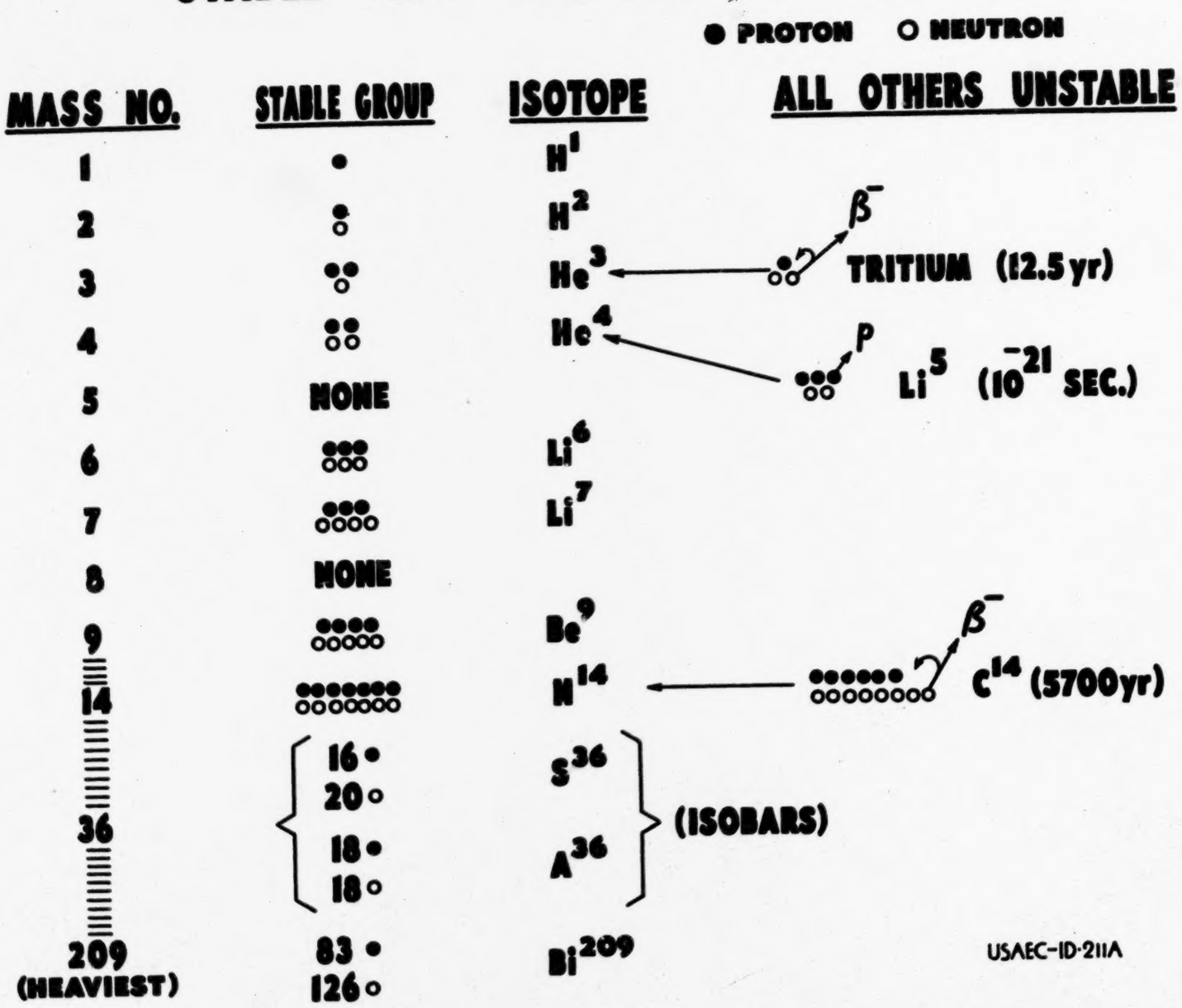
RADIOACTIVE

NUMBER IDENTIFIED	~	1700
NUMBER OCCURRING IN NATURE	~	50
NUMBER DISTRIBUTED FROM REACTORS AND CYCLOTRONS	~	100

USAEC-ID-324A

STABLE AND RADIOACTIVE NUCLEI

● PROTON ○ NEUTRON



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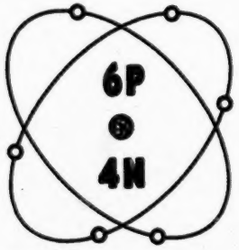
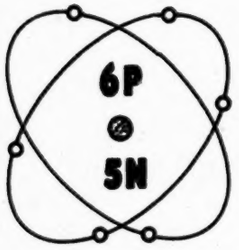
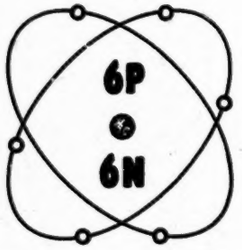
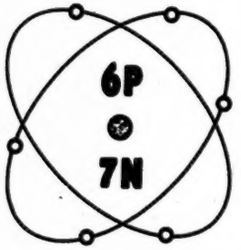
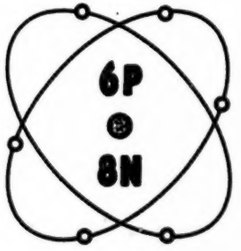
WHAT ARE ISOTOPES

ISOTOPES ARE ATOMS OF AN ELEMENT DISTINGUISHABLE BY THEIR WEIGHT

CARBON 10	CARBON 11	CARBON 12	CARBON 13	CARBON 14
				
6P 4N	6P 5N	6P 6N	6P 7N	6P 8N
MAN-MADE	MAN-MADE	OCCURS IN NATURE	OCCURS IN NATURE	MAN-MADE
RADIOACTIVE	RADIOACTIVE	STABLE	STABLE	RADIOACTIVE

USAEC-ID45A

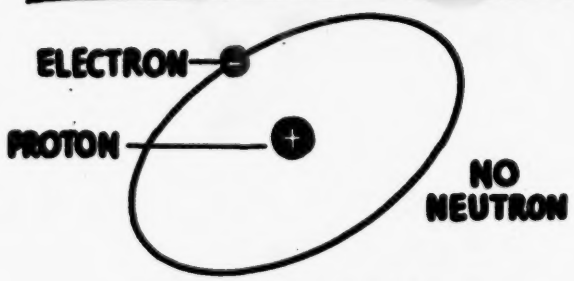
FAMILY of ATOMS

HYDROGEN ATOMS CAN HAVE SEVERAL FORMS

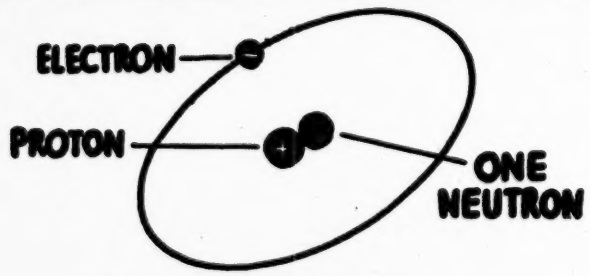
THESE ARE ISOTOPES

NATURAL OCCURRING	NATURAL OCCURRING	MAN-MADE

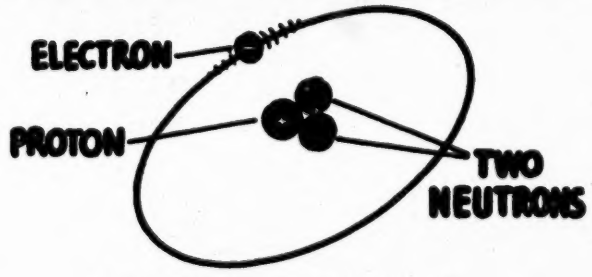
All Hydrogen Atoms Have One Proton



HYDROGEN 1
STABLE



HYDROGEN 2
STABLE



HYDROGEN 3
RADIOACTIVE

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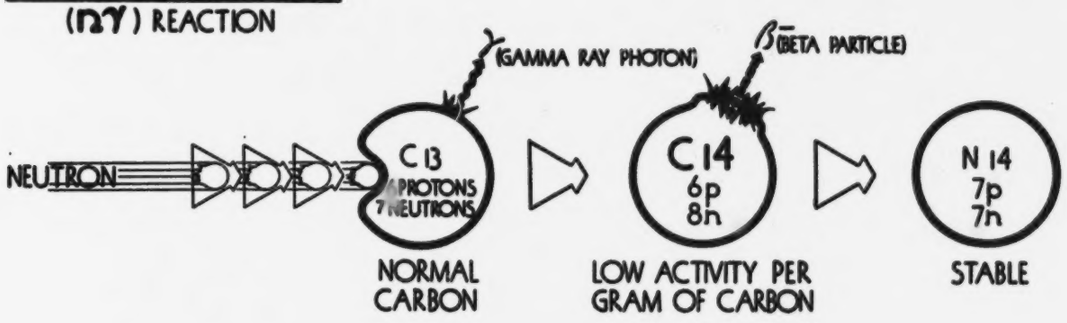
USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

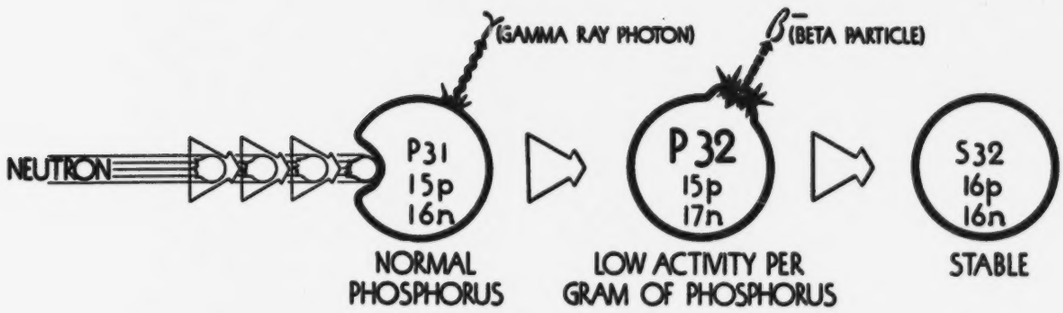
ILLUSTRATIONS OF ISOTOPE PRODUCTION AND AVAILABILITY

PILE PRODUCTION OF RADIOISOTOPES

NEUTRON CAPTURE

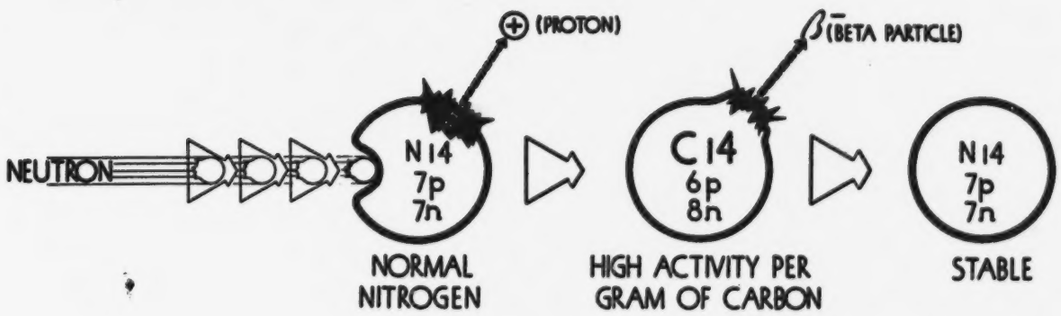
(n,γ) REACTION

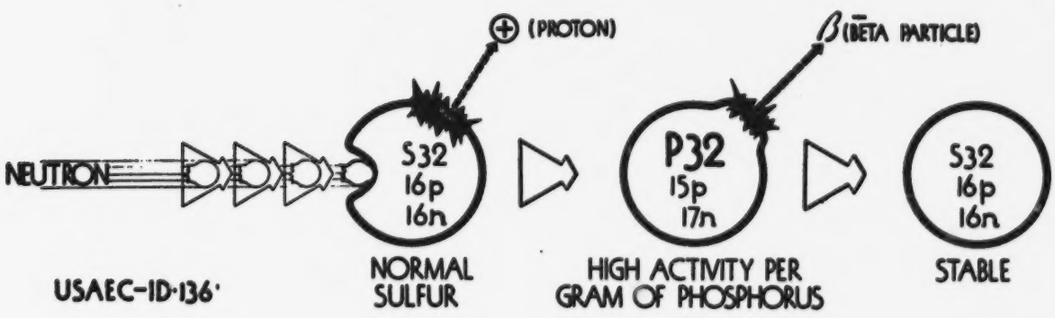




TRANSMUTATION

(n,p) REACTION





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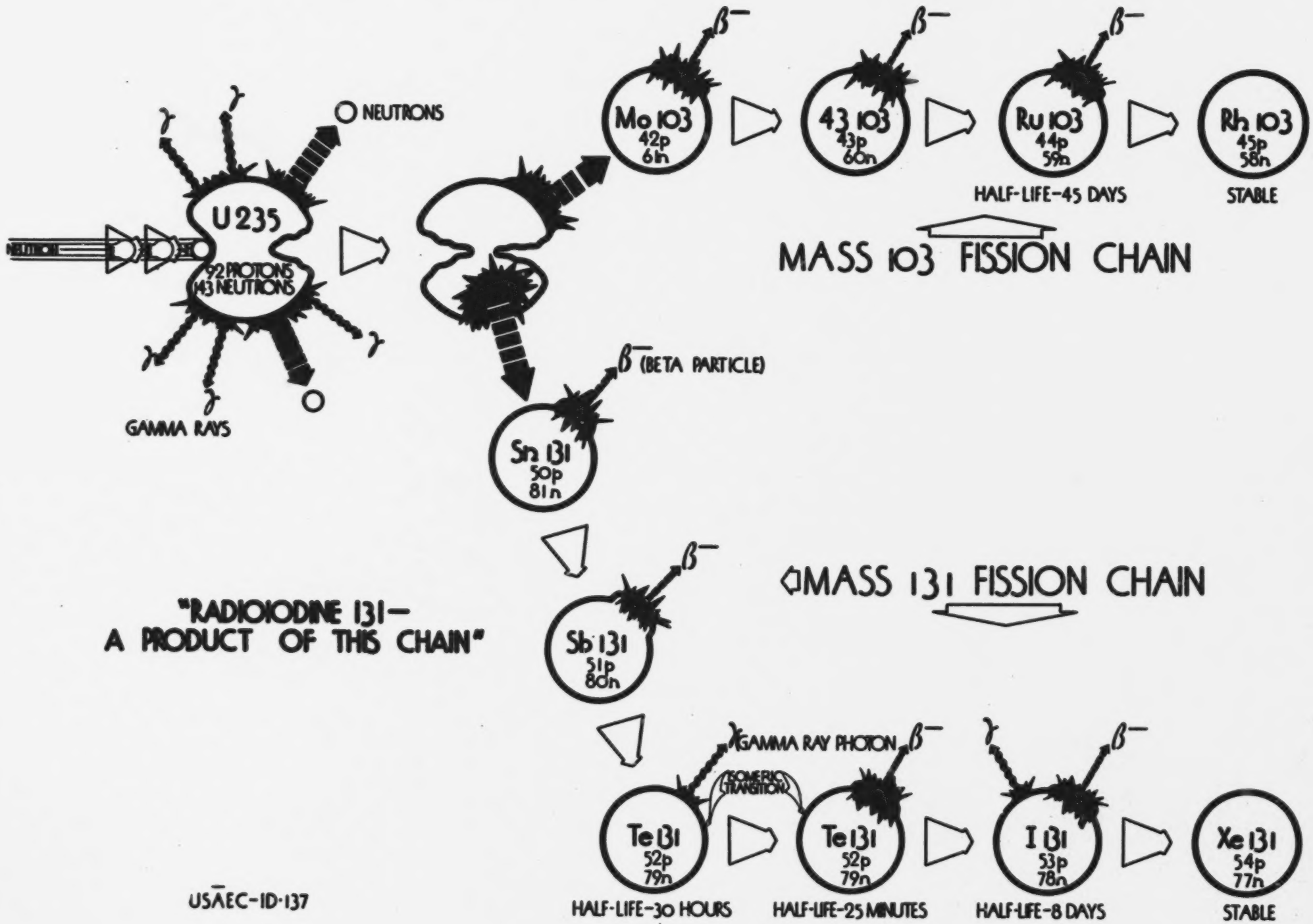
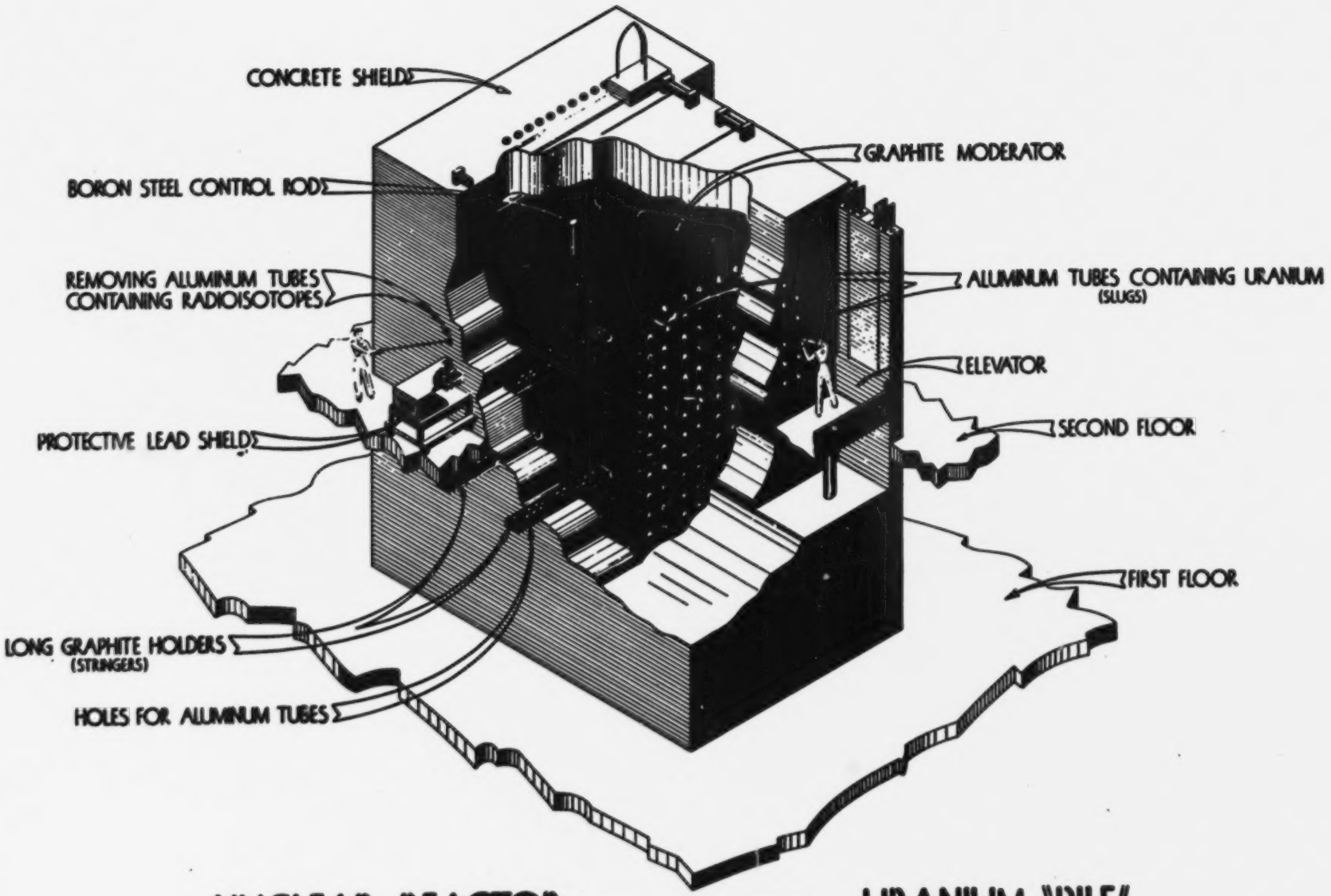
URANIUM FISSION AND BETA CHAIN DECAY



"RADIOIODINE 131—
A PRODUCT OF THIS CHAIN"

USAEC-ID-137



NUCLEAR REACTOR ——— URANIUM "PILE"

USAEC-ID-138

CHARACTERISTICS OF OAK RIDGE GRAPHITE REACTOR

TEMPERATURE

AVERAGE GRAPHITE TEMPERATURE ___ 130° C

VOLUME OF COOLING AIR ___ 100,000 cfm

THERMAL NEUTRON FLUX

MAXIMUM ___ 1.2×10^{12} n/cm²/sec.

AVERAGE ___ 5×10^{11} n/cm²/sec.

POWER LEVEL

DESIGN LEVEL ___ 1000 kw

OPERATING LEVEL ___ 3800 kw

USAEC-ID-50A

CHARACTERISTICS OF OAK RIDGE GRAPHITE REACTOR

SIZE

GRAPHITE MODERATOR ..... 24 FOOT CUBE

CONCRETE SHIELDING .....
- 47 FEET LONG
- 38 FEET WIDE
- 32 FEET HIGH
- 7 FEET THICK

FUEL

TYPE ..... NATURAL URANIUM CLAD IN ALUMINUM

SIZE OF FUEL "SLUG" ..... 1.1 INCH DIAMETER BY 4 INCHES LONG

NUMBER OF FUEL CHANNELS 1248

USAEC-ID-51A

NUCLEAR REACTOR-PRODUCED PURE BETA RAY EMITTING RADIOISOTOPES

USEFUL IN CLINICAL STUDIES

ELEMENT	ISOTOPE	HALF-LIFE	MAXIMUM ENERGY OF RADIATION
HYDROGEN	H-3	12.5 YEARS	0.018 MEV.
CARBON	C-14	5570 YEARS	0.155
PHOSPHORUS	P-32	14.3 DAYS	1.701
SULFUR	S-35	87.1 DAYS	0.166
CALCIUM	Ca-45	165 DAYS	0.254
STRONTIUM	Sr-90	28 YEARS	0.61
*YTTRIUM	Y-90	2.54 DAYS	2.18

*RADIOACTIVE DAUGHTER

USAEC-ID-83A

NUCLEAR REACTOR-PRODUCED BETA AND GAMMA RAY EMITTING RADIOISOTOPES

USEFUL IN CLINICAL STUDIES

ELEMENT	ISOTOPE	HALF-LIFE	MAXIMUM ENERGY OF RADIATION BETA	GAMMA
SODIUM	Na-24	15.1 HOURS	1.39 MEV	1.37, 2.75 MEV
POTASSIUM	K-42	12.5 HOURS	2.04, 3.58	1.51
IRON	Fe-55	2.94 YEARS		K X RAY 0.006
IRON	Fe-59	44.3 DAYS	0.27, 0.46	1.10, 1.30
COBALT	Co-60	5.2 YEARS	0.31	1.17, 1.33
IODINE	I-131	8 DAYS	0.33, 0.61	0.080, 0.284, 0.364, 0.637, 0.722
GOLD	Au-198	2.70 DAYS	0.970,	0.411, 0.68, 1.09

USAEC-ID-84A

USEFUL GAMMA RAY EMITTING ISOTOPES

ISOTOPE	HALF-LIFE	GAMMA RAY ENERGIES-Mev	APPROX. SPEC. ACT.*
HIGH ENERGY (OVER 1 Mev)			
Co 60	5.3 y	1.17, 1.33	20 C/g
Ag 110	270 d	10 γ's: 0.676 TO 1.516 0.885(81%), 1.389(33%)	0.65
Eu 152, 154	13, 16 y	~ 0.3, ~ 1.2	?
Ta 182	117 d	33 γ's: 0.0462 TO 1.237 0.66, 0.885, 0.9 MOST INTENSE	7
MEDIUM ENERGY (0.5 TO 1 Mev)			
**Cs 137	37 y	0.662 (2.6m Ba 137)	20 (Cs_2SO_4, d=3.5)
**Ce 144	275 d	0.13 (abundant)	
Pr 144 (DAUGHTER)	17.5 m	2.2 1.5 } <10% 0.7	100
Ir 192	70 d	12 γ's: 0.137 TO 0.651	115
LOW ENERGY (< 0.5 Mev)			
Se 75	127 d	10 γ's: 0.067 TO 0.405	0.15
Tm 170	127 d	0.084,	?
W 185	73.2 d	0.134	0.2
Hg 203	43.5 d	0.286	0.2

*REACTOR NEUTRON FLUX = $7 \times 10^{12} n/cm^2/sec$

**FISSION PRODUCT

USAEC-ID-119A

REACTOR IRRADIATION FACILITIES
FOR
RADIOISOTOPE PRODUCTION

REACTOR	LOCATION	APPROX. FLUX	SAMPLE SIZE	REMARKS
GRAPHITE REACTOR	OAK RIDGE NAT'L LABORATORY	$1 \times 10^{11} - 7 \times 10^{11}$	3/4" DIA. x 2·7/8"-IU 3·1/2" x 3·1/2" x 10"-SI	CHIEF SOURCE OF AEC-SUPPLIED RADIOISOTOPES
BROOKHAVEN REACTOR	BROOKHAVEN NAT'L LABORATORY	$10^{11} - 4 \times 10^{12}$	3/4" DIA. x 2·1/8"-IU 12" x 12" x 24"-SI	IRRADIATION FACILITIES CAN BE COOLED — AIR, WATER, LIQUID NITROGEN
LOW INTENSITY TEST REACTOR-LITR	OAK RIDGE NAT'L LABORATORY	10^{13}	3/8" DIA. x 1·3/4"-IU	SUPPLEMENTS GRAPHITE REACTOR WHERE HIGHER FLUX REQUIRED
MATERIALS TESTING REACTOR-MTR	NAT'L REACTOR TESTING STATION, IDAHO	5×10^{13}	DEPENDS ON AVAILABLE "RABBIT" OR HOLE	PRINCIPALLY FOR PRODUCTION OF LONG-LIVED MATERIALS
ARGONNE RESEARCH REACTOR-CP-5	ARGONNE NAT'L LABORATORY	5×10^{12}	———	AVAILABLE PRIMARILY TO PARTICIPATING UNIV'S.

IU — IRRADIATED UNIT
SI — SERVICE IRRADIATION

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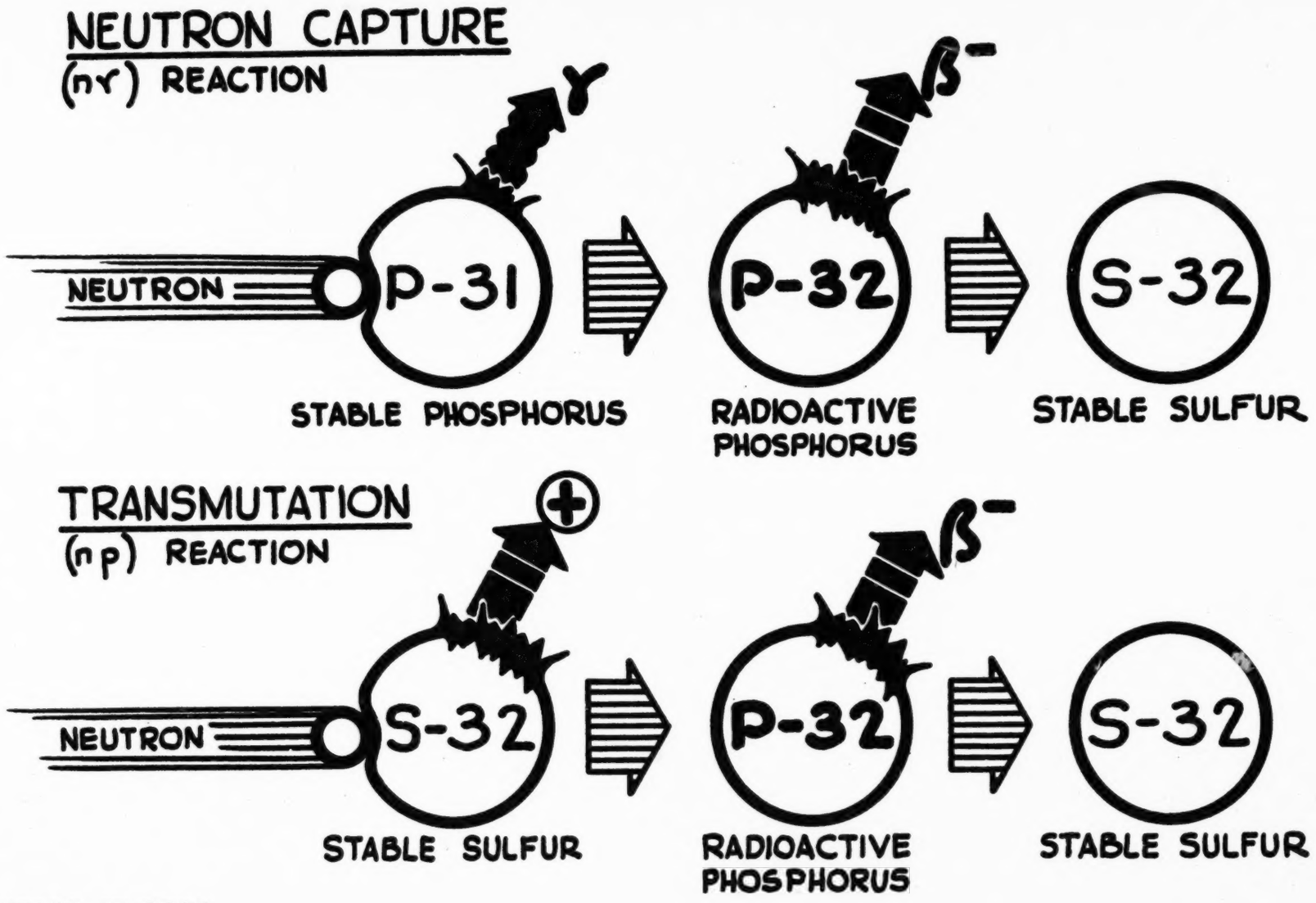
PRODUCTION OF RADIOISOTOPES



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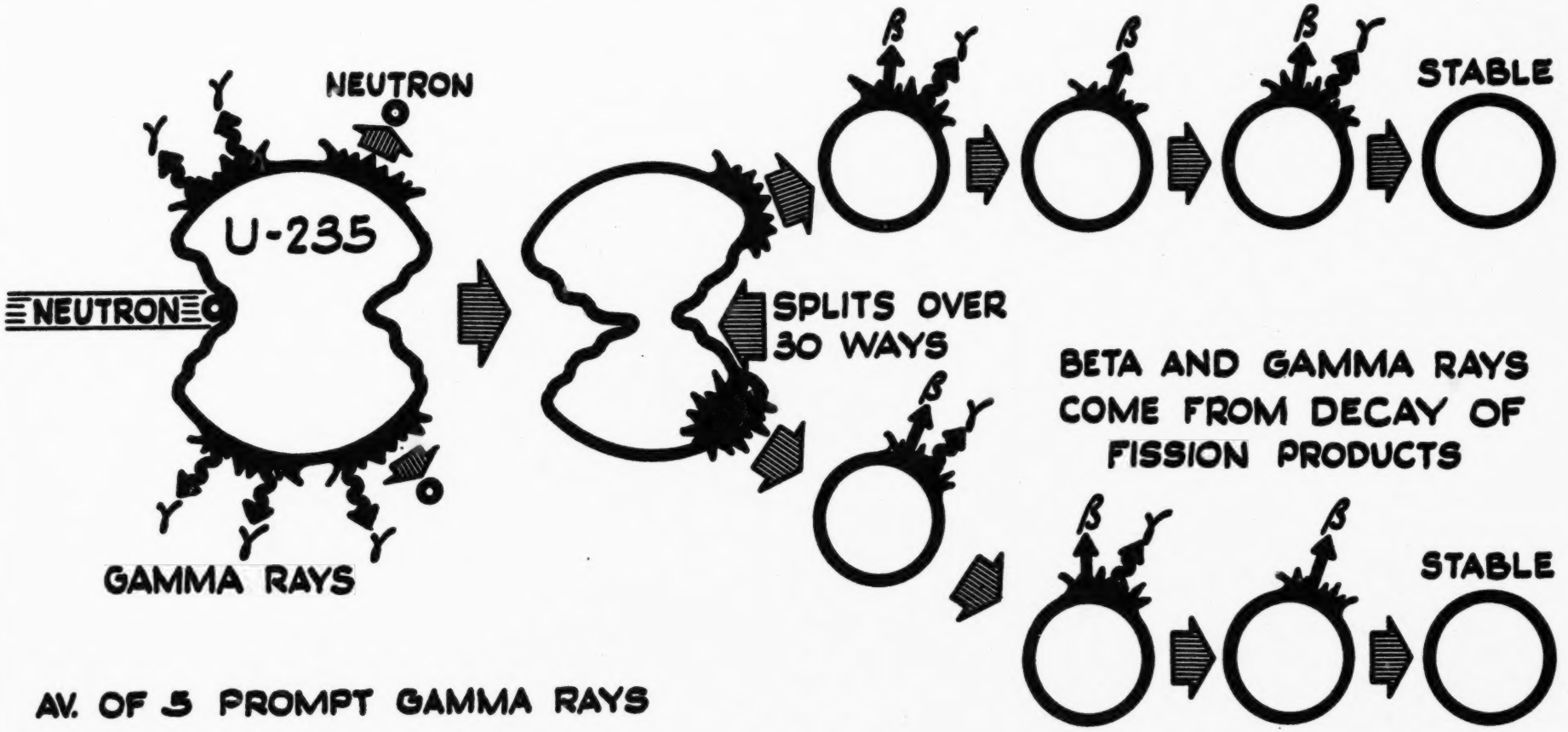
Uranium Fission Process



AV. OF 5 PROMPT GAMMA RAYS

AV. OF 2.5 NEUTRONS
(99% PROMPT, 1% DELAYED)

- FISSION PRODUCTS TOTAL ABOUT 200 RADIOACTIVE SPECIES.
- ATOMIC NUMBERS 30 TO 64
- MASSES 72 TO 161
- (Zn 72 TO Gd 161)

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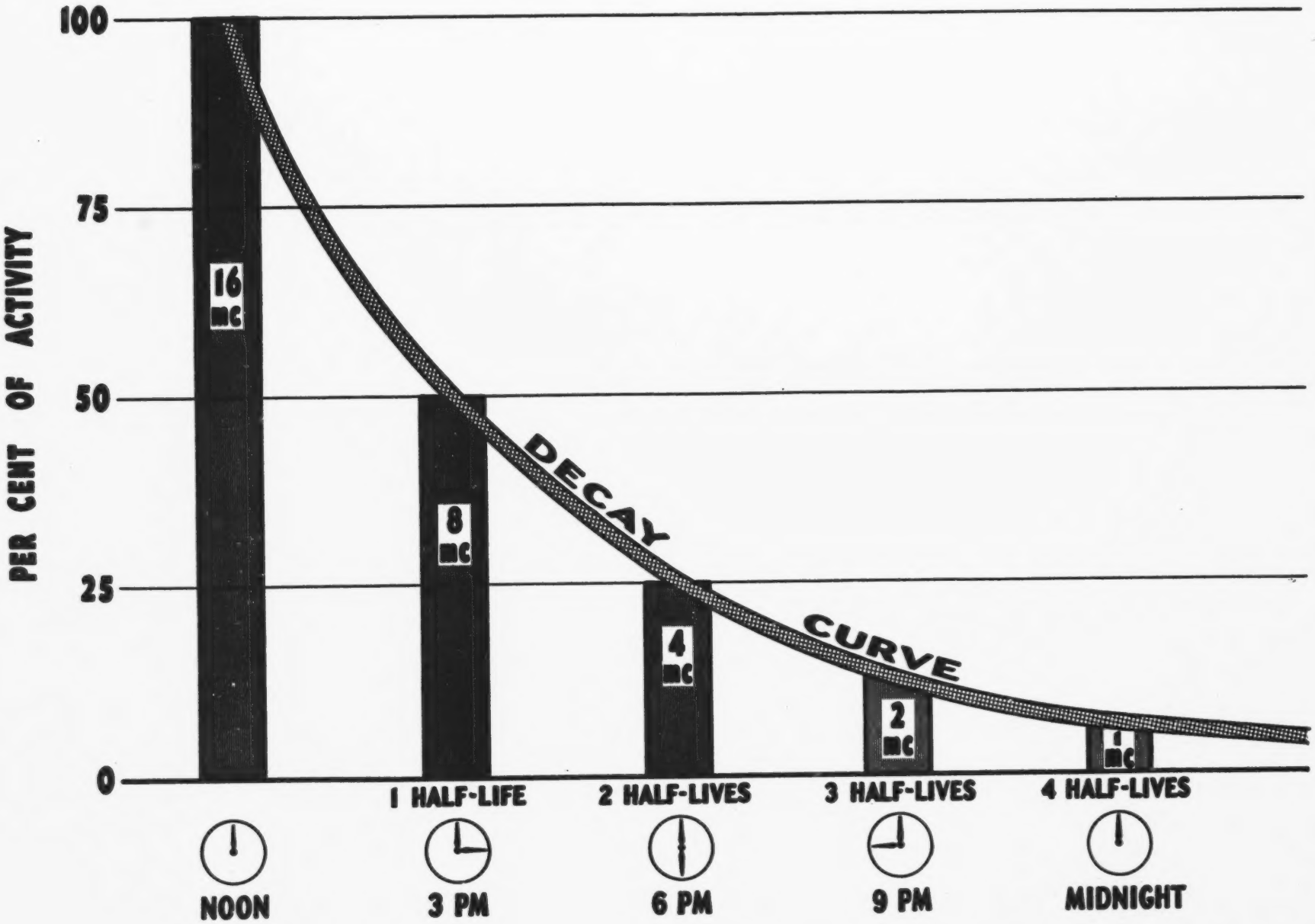
ILLUSTRATIONS OF ISOTOPE CHARACTERISTICS

THE MEANING OF HALF-LIFE



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PROPERTIES OF RADIOACTIVE COBALT

PHYSICAL:

METALLIC —— MAGNETIC —— NON-CORROSIVE

EASILY MACHINED —— HIGH SPECIFIC GRAVITY (~ 8.8)

RADIOACTIVE:

LONG HALF-LIFE (5.2 YR) —— WEAK BETA RAY (0.3 MEV)

MONO-ENERGETIC GAMMA RAYS (1.16 AND 1.31 MEV)

AVAILABILITY:

LARGE QUANTITIES AT LOW COST

WIDE RANGE OF ACTIVITIES PER GRAM

USAEC-ID-389

EFFECTS OF TOTAL BODY ACUTE RADIATION

ACUTE DOSE	PROBABLE EFFECT
0–25 r	NO OBVIOUS INJURY
25–50 r	POSSIBLE BLOOD CHANGES BUT NO SERIOUS INJURY
100–200 r	INJURY, POSSIBLE DISABILITY
200–400 r	INJURY AND CERTAIN DISABILITY, DEATH POSSIBLE
400– r	FATAL TO 50%
600 OR MORE	FATAL

USAEC–ID 494

MAXIMUM PERMISSIBLE TISSUE DOSE "REPS" PER WEEK

TYPE OF RADIATION	AT ANY POINT WITHIN BODY	RBE*	IN THE BASAL LAYER OF THE EPIDERMIS	
			EXPOSURE OF ENTIRE BODY	EXPOSURE OF HANDS ONLY
X-RAYS & GAMMA RAYS	0.3	1	0.5	1.5
BETA RAYS	0.3	1	0.5	1.5
PROTONS	0.03	10	0.05	0.15
ALPHA RAYS	0.015	20	0.025	0.075
FAST NEUTRONS	0.03	10	0.05	0.15
THERMAL NEUTRONS	0.06	5	0.1	0.3

*RBE - RELATIVE BIOLOGICAL EFFECTIVENESS

USAEC-ID 495

COMPARATIVE GAMMA RAY OUTPUT
FROM
ONE CURIE SOURCES*
(ASSUMING NO SELF-ABSORPTION)

ISOTOPE	HALF-LIFE	APPROX. r/hr/1m
Au 198	2.7d	0.22
I-131	8.0d	0.24
Cs 137	37y	0.36
Ta 182	117d	0.61
Ra 226 (0.5mm Pt filter)	1620y	0.84
Co 60	5.2y	1.30

*1 CURIE = 37 BILLION DISINTEGRATIONS/SEC

USAEC-ID-64A

APPROXIMATE GAMMA RAY OUTPUT AND SOURCE VOLUME
(ASSUMING NO SELF-ABSORPTION)

COBALT 60

CURIES	VOLUME SPEC. ACT. 5C/g	VOLUME SPEC. ACT. 25C/g	r/min./50 cm	r/min/1m
500	11 cm^3	2.2 cm^3	44	11
1000	22	4.4	88	22
1500	33	6.6	132	33

CESIUM 137

CURIES	VOLUME DENSITY ($Cs_2 SO_4$)=3.5	r/min./50 cm	r/min/1m
1000	13.5 cm^3	17	4
5000	67.5	85	21
10000	135	170	42

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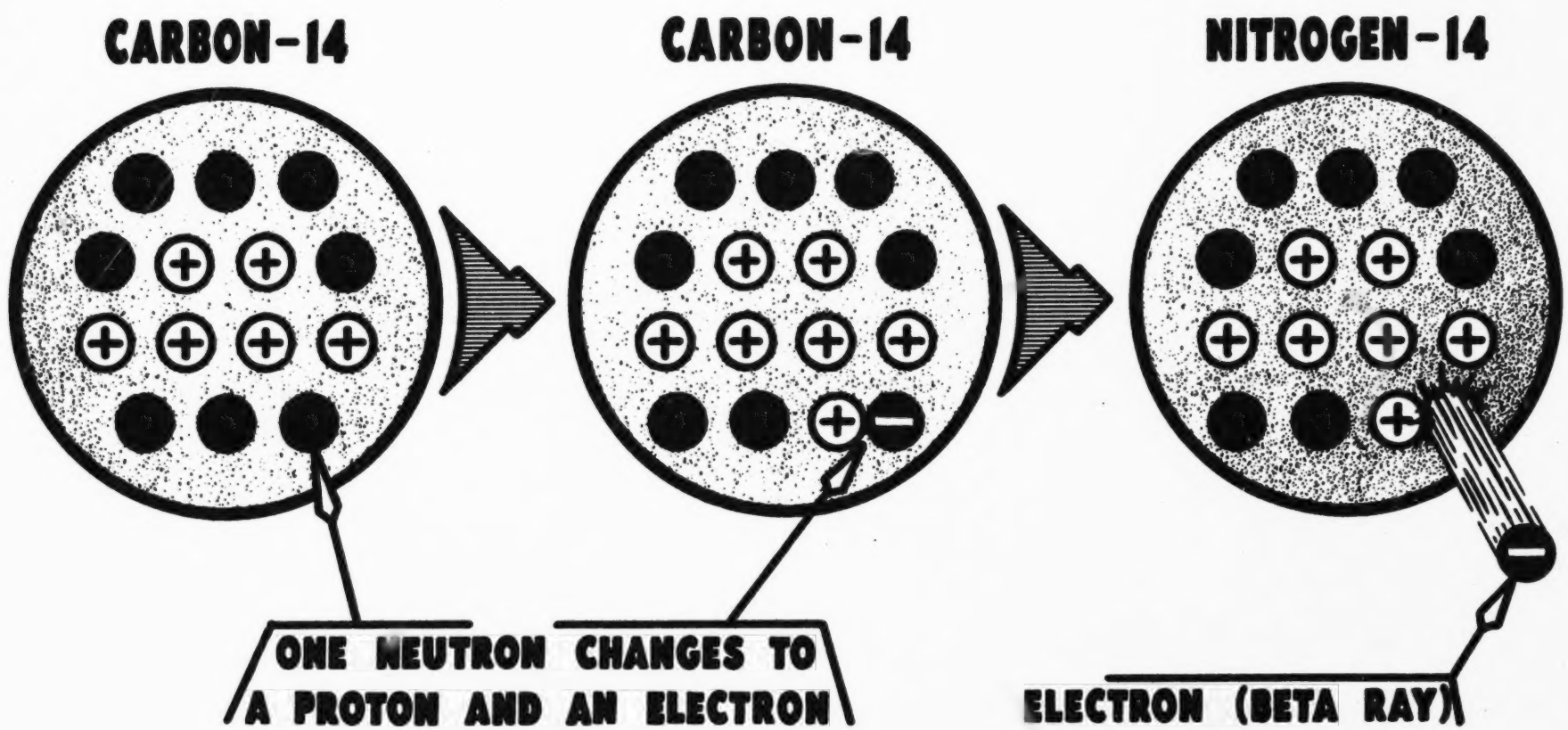
RADIOACTIVITY OF CARBON—14



⊕ PROTON

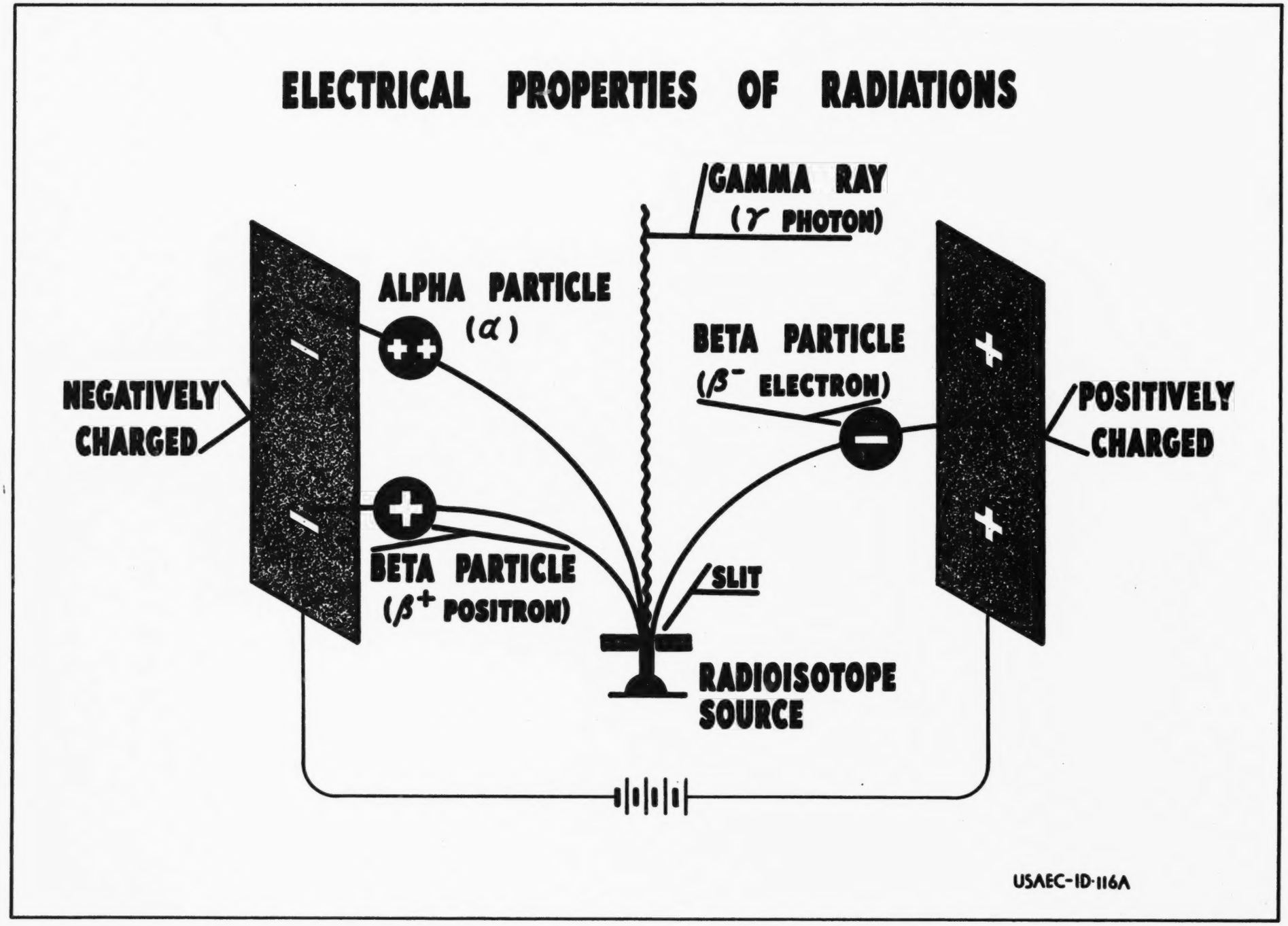
● NEUTRON

⊖ ELECTRON

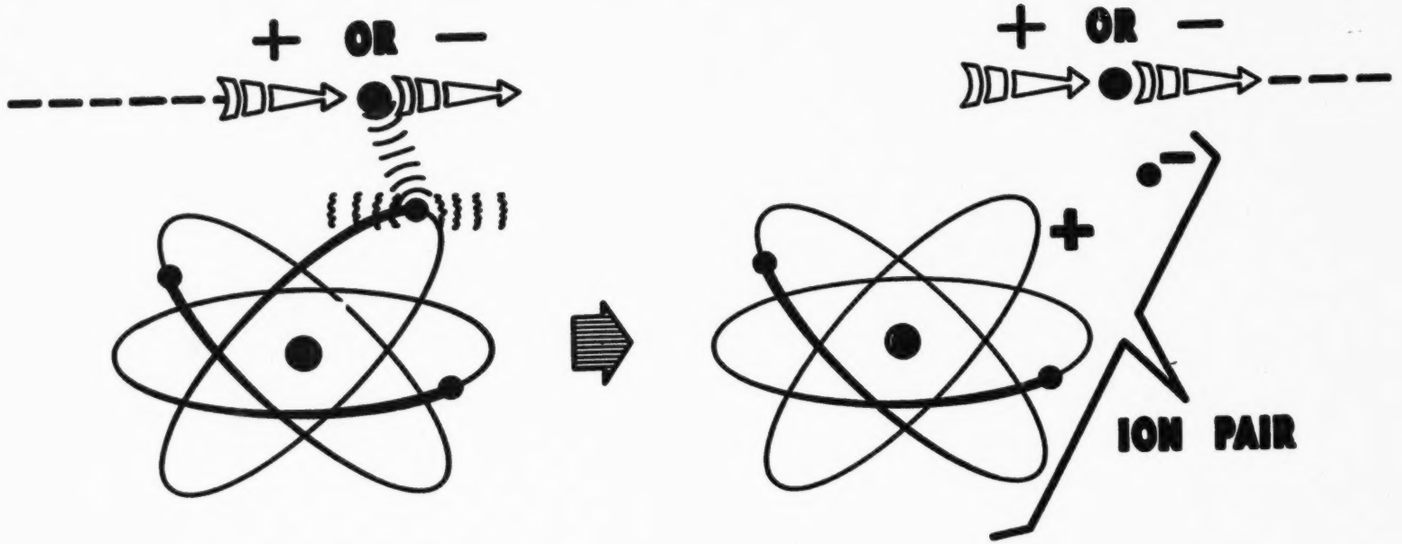
CARBON-14 — PURE BETA-RAY EMITTER

HALF-LIFE — 5740 YEARS

USAEC-ID-105A


ELECTRICAL PROPERTIES OF RADIATIONS
GAMMA RAY
(γ PHOTON)
ALPHA PARTICLE
(α)
BETA PARTICLE
(β⁻ ELECTRON)
NEGATIVELY
CHARGED
POSITIVELY
CHARGED
BETA PARTICLE
(β⁺ POSITRON)
SLIT
RADIOISOTOPE
SOURCE
USAEC-ID-116A

IONIZATION BY CHARGED PARTICLE

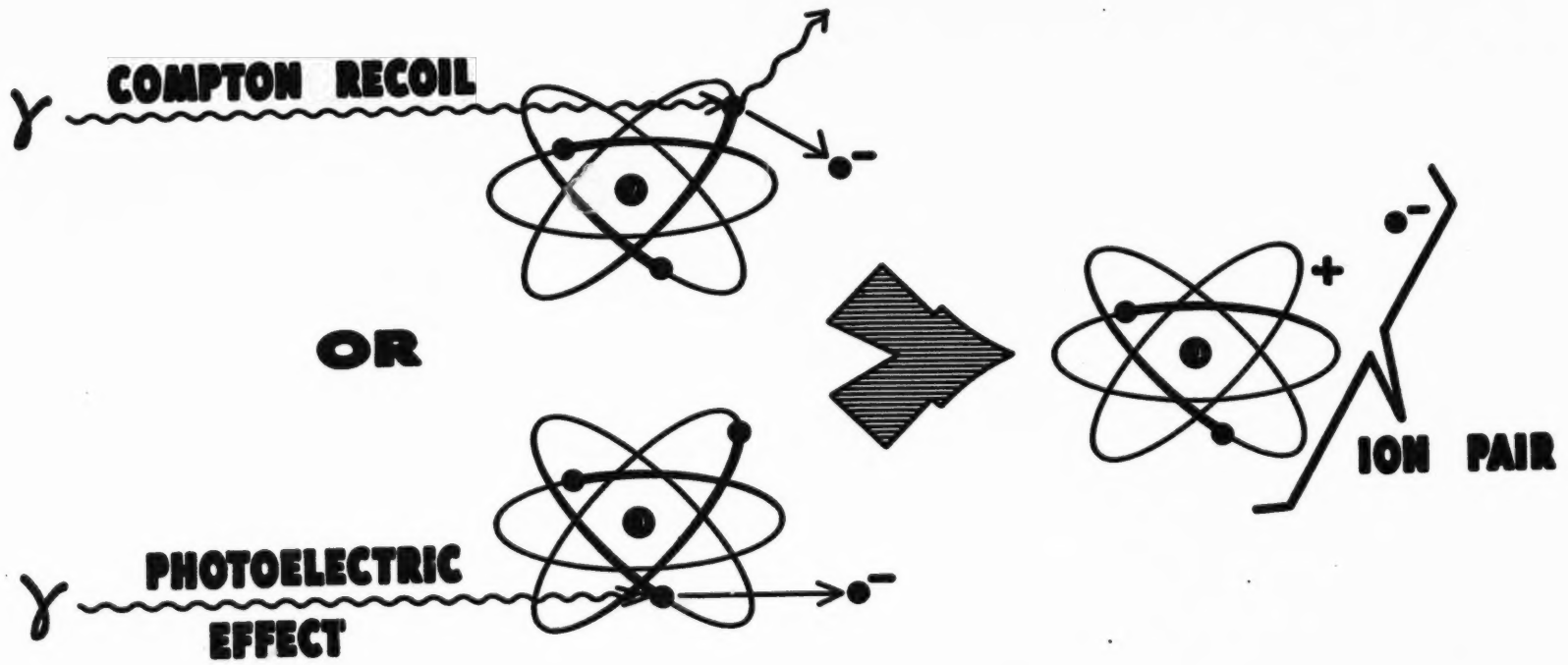


ELECTRON IS GIVEN SUFFICIENT ENERGY TO EJECT IT

IONS THEN:
- **REACT CHEMICALLY WITH MATTER**
- **MOVE IN ELECTRIC FIELDS**
- **RECOMBINE — EMITTING LIGHT**
- **SERVE AS CONDENSATION NUCLEI**

USAEC-ID-191A

IONIZATION BY GAMMA RAYS



ELECTRON IS EJECTED WITH ALL OR PART OF GAMMA ENERGY

IONS THEN: -REACT CHEMICALLY WITH MATTER
-MOVE IN ELECTRIC FIELDS
-RECOMBINE — EMITTING LIGHT
-SERVE AS CONDENSATION NUCLEI

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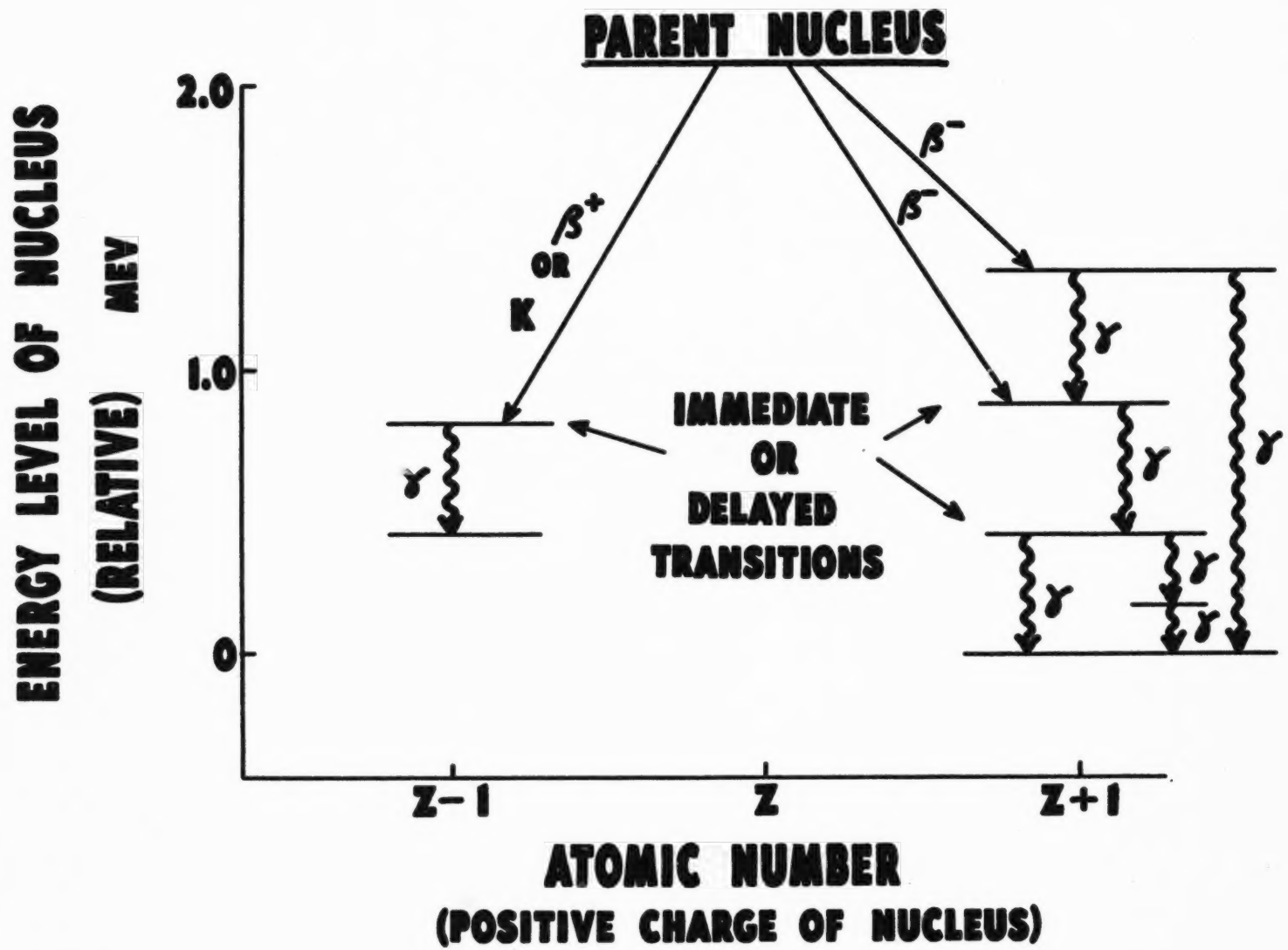
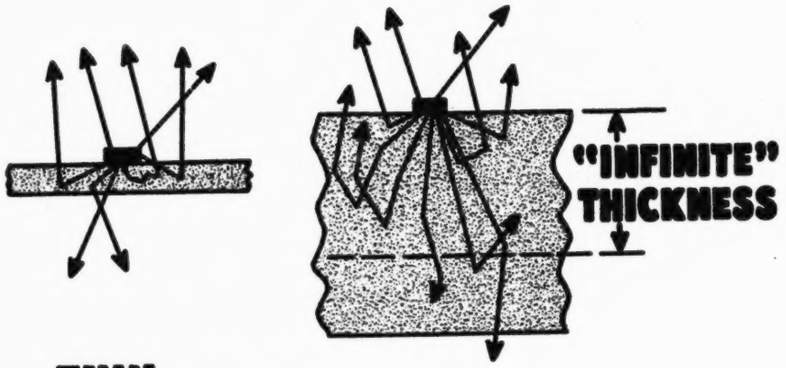
THE ENERGY LEVEL DIAGRAM



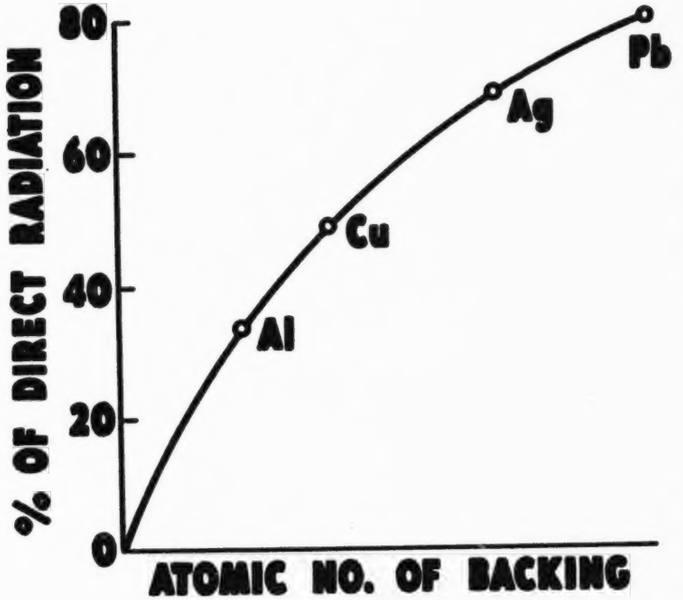
USAEC-ID-209A

BACKSCATTERING OF BETA PARTICLES



THIN BACKING

THICK BACKING

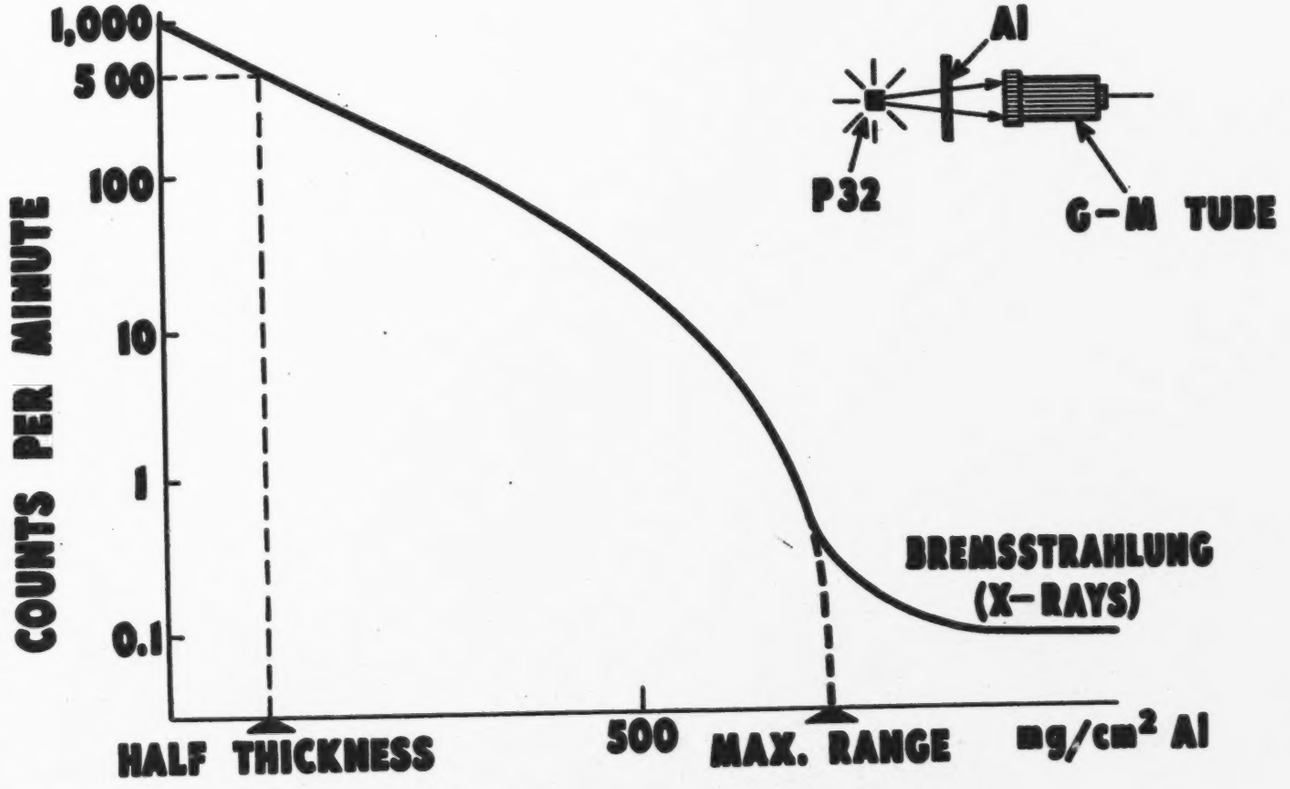


EXTENT OF "SATURATION" BACKSCATTERING

- BACKSCATTERING INCREASES WITH THICKNESS
- "SATURATION" OCCURS AT "INFINITE THICKNESS" (APPROX. ½ MAX. RANGE)

USAEC-ID-214A

RANGE OF BETA PARTICLES

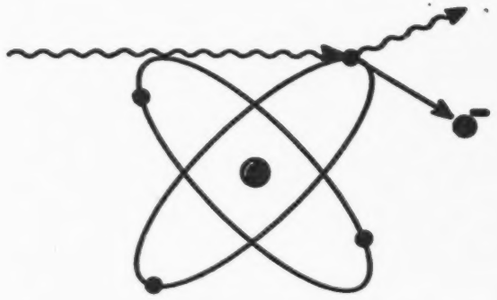


P 32 β PARTICLES IN ALUMINUM

- ABSORPTION IS PRACTICALLY EXPONENTIAL AT START
- MAXIMUM RANGE USUALLY 7 OR 8 TIMES ½ THICKNESS

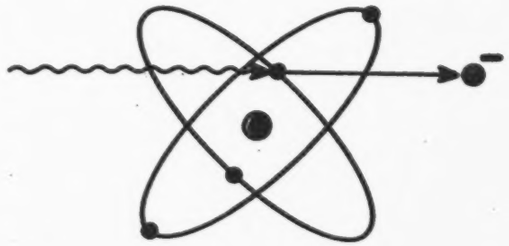
USAEC-ID-215A

GAMMA RAY INTERACTIONS



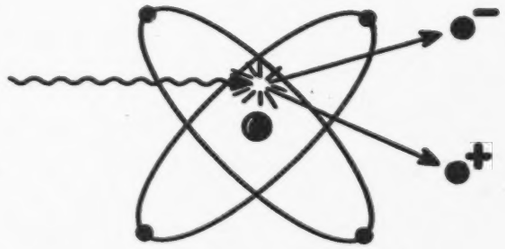
COMPTON RECOIL PROCESS

- γ RAY OF LOWER ENERGY PROCEEDS IN NEW DIRECTION
- ELECTRON IS EJECTED WITH THE ENERGY DIFFERENCE



PHOTOELECTRIC PROCESS

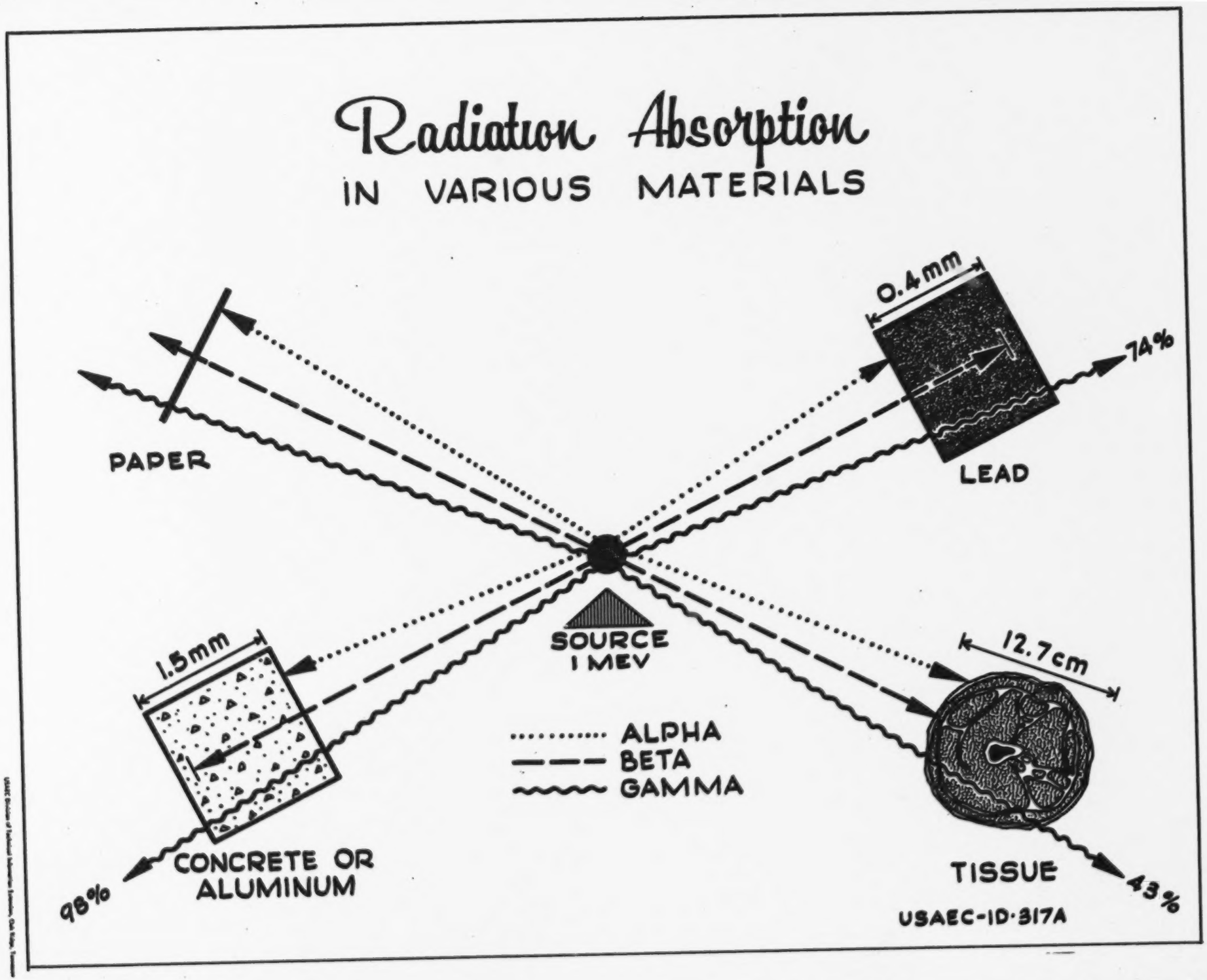
- γ RAY COMPLETELY ABSORBED
- ELECTRON EJECTED WITH γ RAY'S ENERGY MINUS BINDING ENERGY



PAIR PRODUCTION PROCESS

- γ RAY ANNIHILATED
- ELECTRON AND POSITRON CREATED AND SHARE γ RAY'S ENERGY MINUS 1.02 Mev

USAEC-ID-216A


Radiation Absorption
IN VARIOUS MATERIALS
0.4mm
74%
PAPER
LEAD
SOURCE
1 MEV
1.5mm
12.7cm
ALPHA
BETA
GAMMA
98%
CONCRETE OR
ALUMINUM
TISSUE
43%
USAEC-ID-317A

ILLUSTRATIONS OF ISOTOPE APPLICATIONS

RADIOACTIVE ISOTOPES

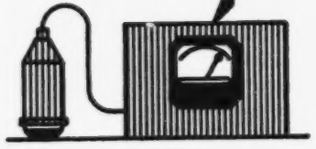
FOR DISTRIBUTION STUDIES OF AN ELEMENT IN END PRODUCTS

① ADD KNOWN AMOUNT OF ELEMENT "A" AND ITS RADIOISOTOPE "A*" TO

BIOLOGICAL
CHEMICAL
OR
PHYSICAL REACTION

② PRODUCTS CHEMICALLY SEPARATED

③ RADIOCHEMICAL DETERMINATION OF "A" IN EACH PRODUCT



ADVANTAGES:

1 - RADIOCHEMICAL ANALYSIS ALONE SHOWS AMOUNT OF 'A' IN EACH PRODUCT

2 - SENSITIVITY IS 10^{-19} GRAMS FOR SHORT-LIVED ISOTOPE

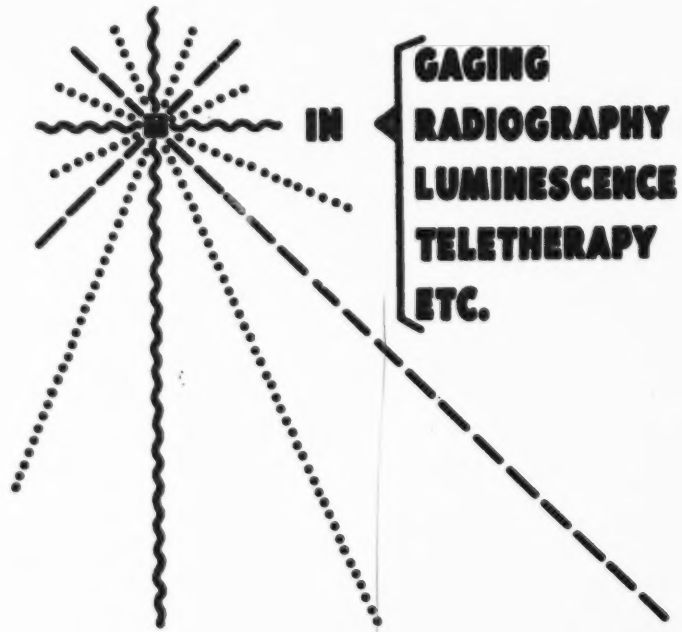
LIMITATIONS:

1 - COMPLETE CHEMICAL SEPARATION REQUIRED FOR RADIOCHEMICAL ANALYSIS

USAEC-ID-238

HOW RADIOISOTOPES CAN BE USED

AS SOURCES OF RADIATION

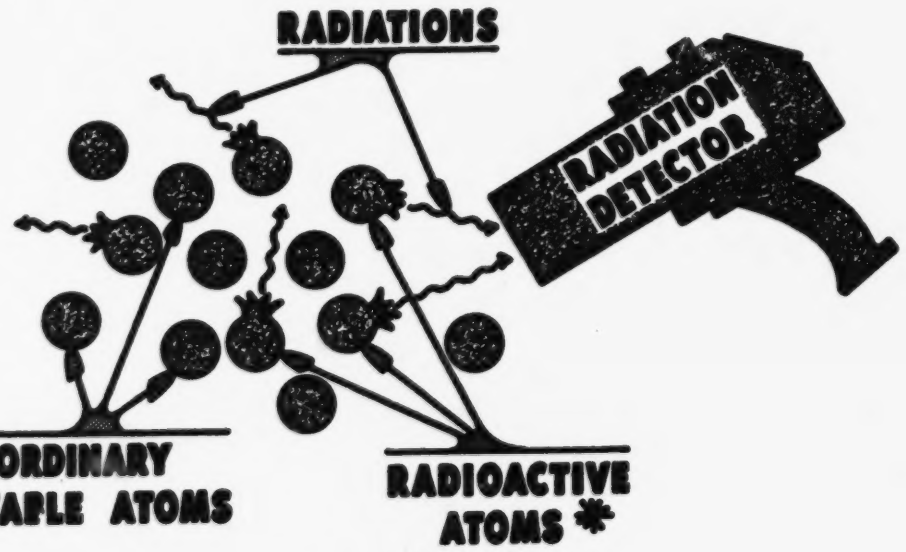


IN

- GAGING
- RADIOGRAPHY
- LUMINESCENCE
- TELETHERAPY
- ETC.

VARIETY OF RADIATIONS
LOW COST
COMPACT SOURCES OF HIGH ACTIVITY

AS TRACER ATOMS

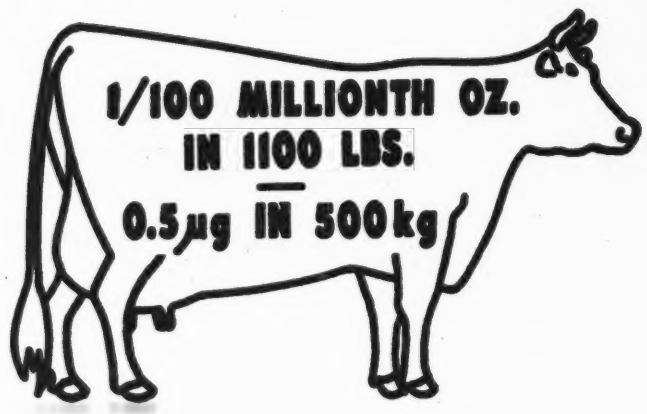


*RADIOACTIVE ATOMS BEHAVE LIKE STABLE ATOMS ——
ARE TRACED BY RADIATIONS

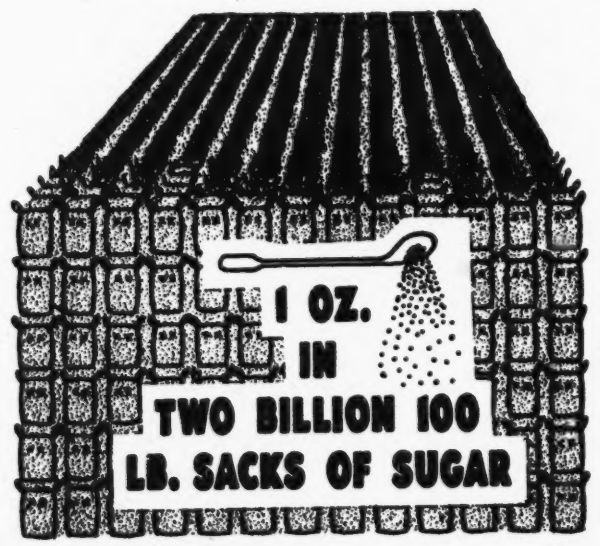
USAEC-ID-48A

POWER OF ISOTOPE TRACER METHOD

SENSITIVITY:- DILUTIONS OF A TRILLION (10^{12})



OR



SPECIFICITY:- CAN TRACE SPECIFIC BATCHES OF ATOMS AND MOLECULES IN SPITE OF:

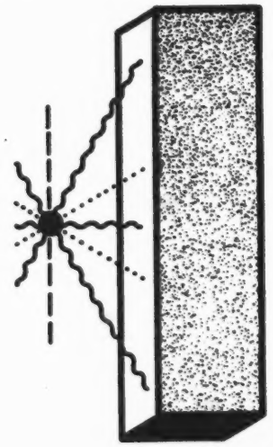
A—OTHER KINDS OF ATOMS AND MOLECULES

B—NUMEROUS AND COMPLEX CHEMICAL REACTIONS

USAEC-ID-89A

BASIC PRINCIPLES OF RADIOISOTOPE UTILIZATION

RADIATION AFFECTS MATERIALS



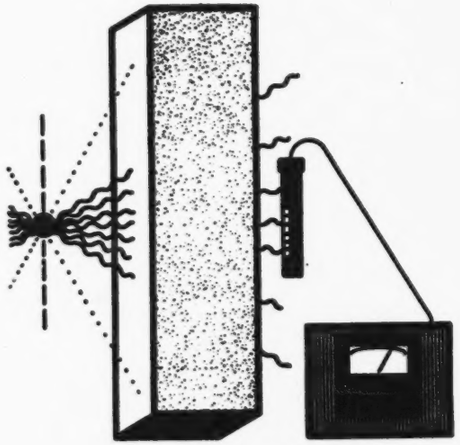
FOOD & DRUG STERILIZATION

STATIC ELECTRICITY ELIMINATION

TELETHERAPY

RADIATION GENETICS

MATERIALS AFFECT RADIATION



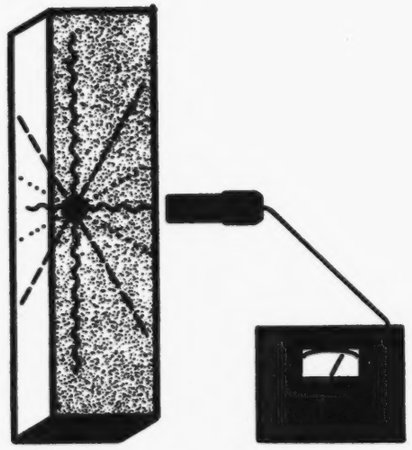
CLINICAL RADIOGRAPHY

THICKNESS (DENSITY) GAGING

INDUSTRIAL RADIOGRAPHY

LIQUID LEVEL & HEIGHT INDICATION

RADIATION TRACES MATERIALS



METABOLIC STUDIES

FLUID FLOW

ABRASION & WEAR MEASUREMENT

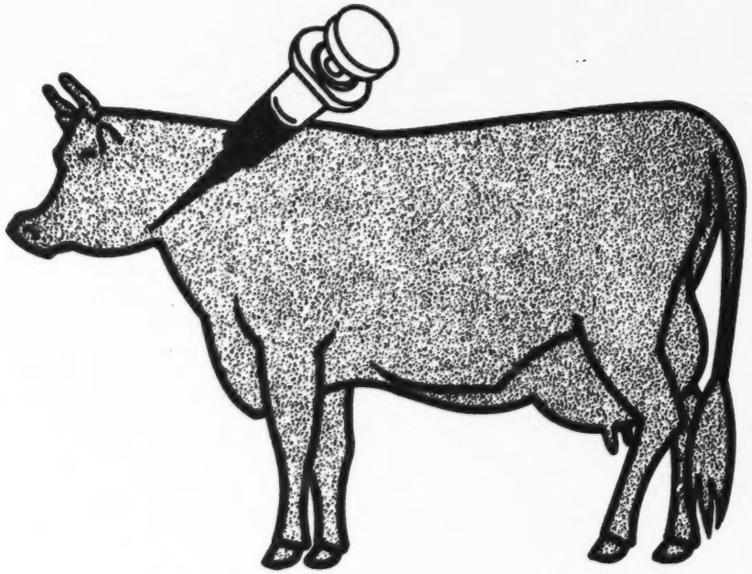
STUDY OF REACTION MECHANISMS

USAEC-ID-298A

Tracing with Radioisotopes

USING

CARBON—14



1 MILLIGRAM OF C 14 EMITS 200,000,000 RADIOACTIVE SIGNALS/SEC.

.. 1 mg C14 IN A DRUG, VITAMIN OR HORMONE INJECTED INTO A 1000 POUND COW—CAN STILL BE MEASURED IN 10 mg AMOUNTS OF BLOOD, MILK OR TISSUE.

USAEC-ID-299A

RADIOACTIVITY HAS LABELED AND TRACED

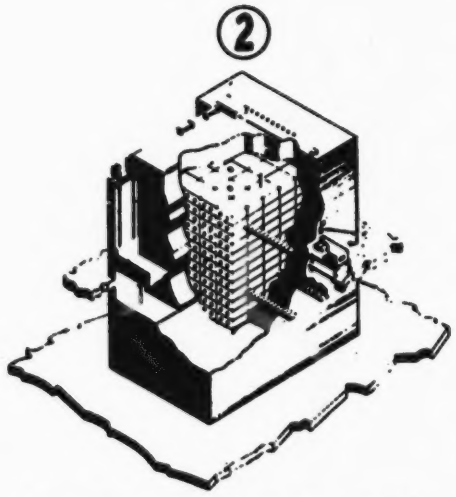
ELEMENTS	BIOCHEMICALS	MATERIALS	ORGANISMS
HYDROGEN	AMINO ACIDS	WATER	BLOOD CELLS
CARBON	SUGARS	SALT	VIRUSES
PHOSPHORUS	STARCH	SOAP	BACTERIA
CALCIUM	VITAMINS	WAXES	MOSQUITOES
COPPER	HORMONES	GASOLINE	BEETLES
GOLD	ANTIBIOTICS	PISTON RINGS	BIRDS
MENDELEVIUM (101)	CARCINOGENS	RUBBER	RATS

USAEC-ID-329A

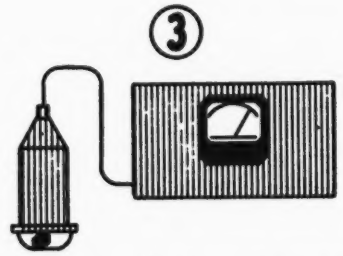
INDUCTION OF RADIOACTIVITY

FOR ACTIVATION ANALYSIS

SAMPLE CONTAINING UNKNOWN ELEMENTS



SAMPLE IRRADIATED WITH NEUTRONS IN NUCLEAR REACTOR



INDUCED RADIOISOTOPES IDENTIFIED BY RADIATION CHARACTERISTICS

ADVANTAGES:

1 - ELIMINATES TEDIOUS CHEMICAL PROCEDURES

2 - MORE SENSITIVE THAN CHEMICAL AND SPECTROSCOPIC METHODS

3 - METHOD IS BOTH QUALITATIVE AND QUANTITATIVE

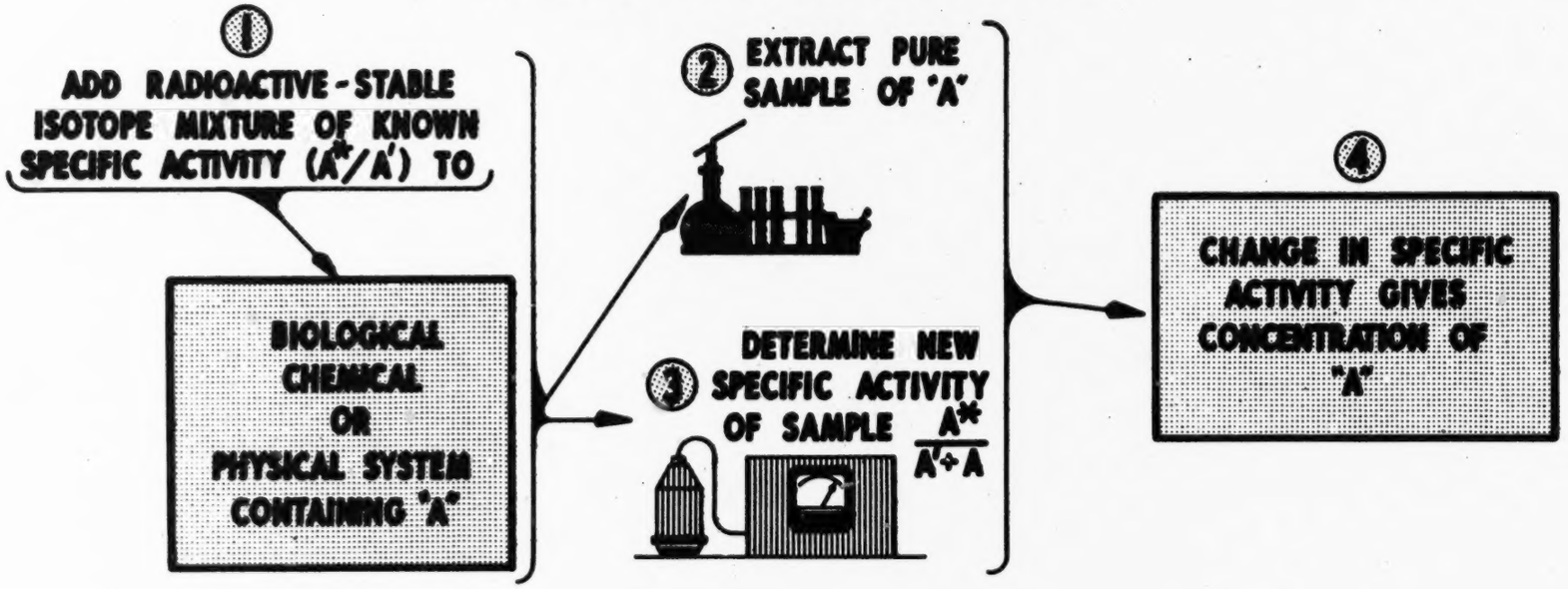
DISADVANTAGES:

1 - LARGE SOURCE OF NEUTRONS SUCH AS A REACTOR IS NEEDED

2 - SIMILAR RADIATION PROPERTIES MAY PREVENT DIFFERENTIATION OF INDUCED RADIOISOTOPES

ID-USAEC

RADIOACTIVE ISOTOPES
FOR ISOTOPE DILUTION ANALYSIS



ADVANTAGES:

1 - SENSITIVITY MANY TIMES GREATER THAN CHEMICAL ANALYSIS

2 - QUANTITATIVE CHEMICAL SEPARATION PROCEDURES NOT NECESSARY

LIMITATIONS:

1 - SPECIFIC ACTIVITY SHOULD CHANGE BY A FACTOR OF 2 OR MORE

2 - a. ISOTOPE MIXTURE ADDED
b. SAMPLE ISOLATED FOR ANALYSIS } MUST BE CHEMICALLY PURE

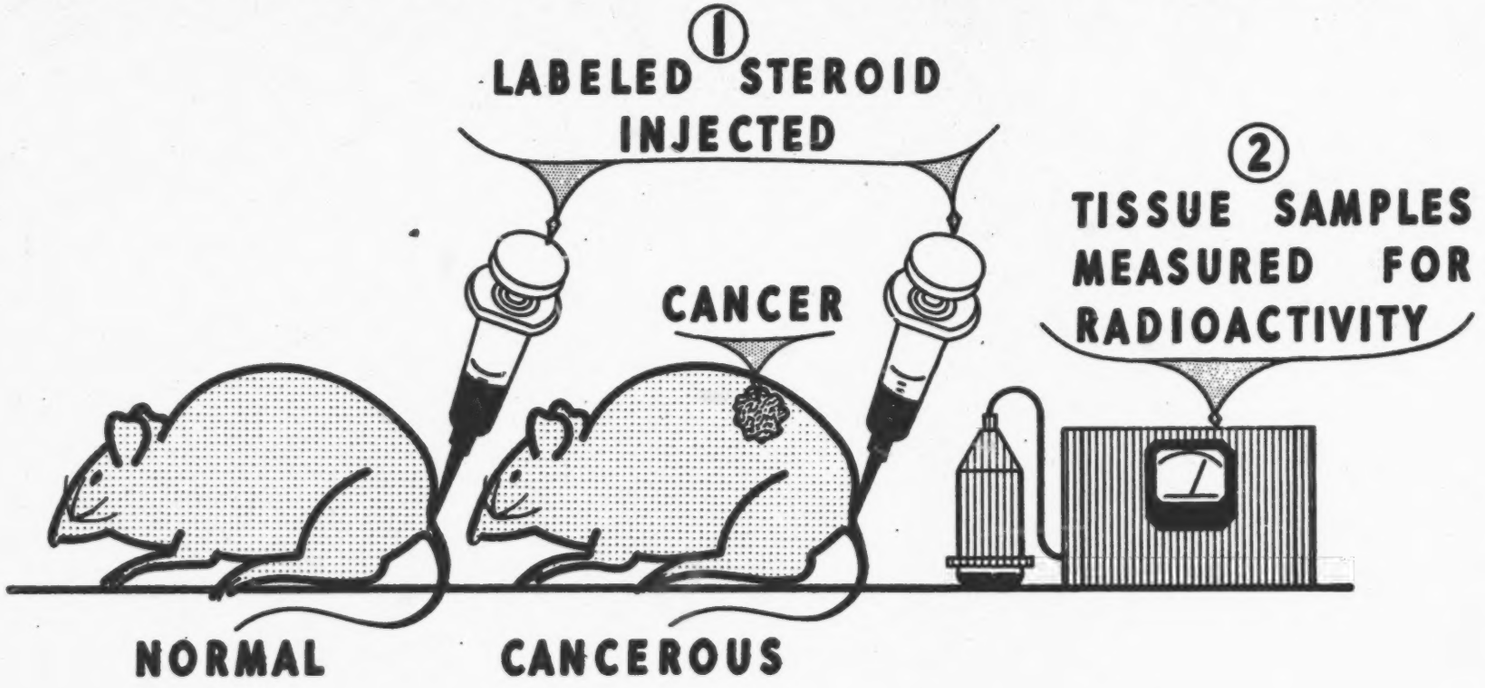
ID-USAEC

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

ILLUSTRATIONS OF ISOTOPE APPLICATIONS IN BIOLOGY AND MEDICINE, RESEARCH

RADIOACTIVE CARBON – C 14

FOR STUDYING FATE OF LABELED STEROIDS



INDICATES:

1- UPTAKE OF STEROIDS IN VARIOUS ORGANS

2- FATE OF STEROIDS IN EACH ANIMAL

3- REASONS FOR DIFFERENCES DUE TO DISEASE

USAEC-ID-178

RADIOACTIVE SULFUR – S35

FOR STUDY OF BODY'S USE OF AMINO ACIDS

① S35 INCORPORATED IN AMINO ACIDS:

- 1- METHIONINE
- 2- GLUTATHIONE
- 3- CYSTINE

} ESSENTIAL BUILDING BLOCKS FOR TISSUE FORMATION

② LABELED AMINO ACIDS FED

③ TISSUE SAMPLES MEASURED FOR S35 CONTENT

SHOWS:

1- UPTAKE OF AMINO ACIDS IN VARIOUS ORGANS

2- HOW AMINO ACIDS ENTER INTO BODY PROCESSES

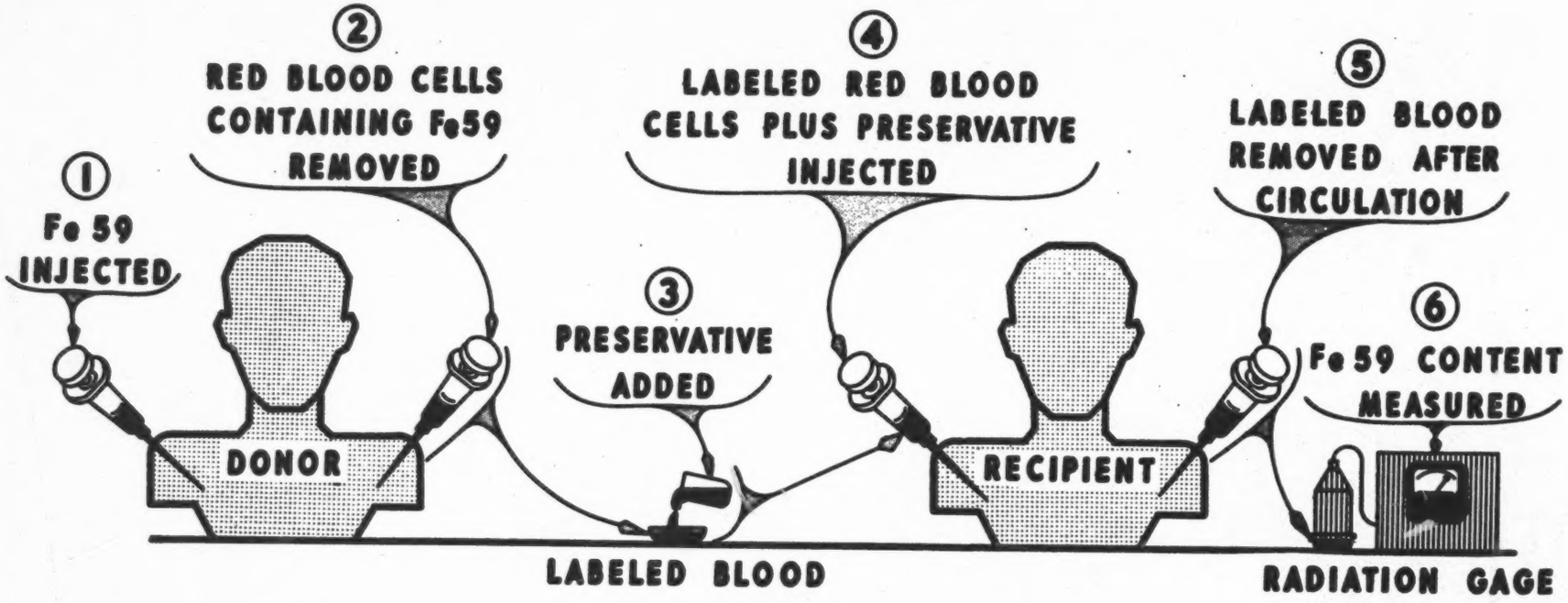
3- DIFFERENCE IN UPTAKE AND USE DUE TO DISEASES

CANCER - CIRRHOSIS - DIABETES - VITAMIN DEFICIENCY

USAEC-ID-182

RADIOACTIVE IRON – Fe 59

FOR STUDYING WHOLE BLOOD PRESERVATION



SHOWS:

1 - Fe 59 IN BLOOD AS FUNCTION OF CIRCULATION TIME

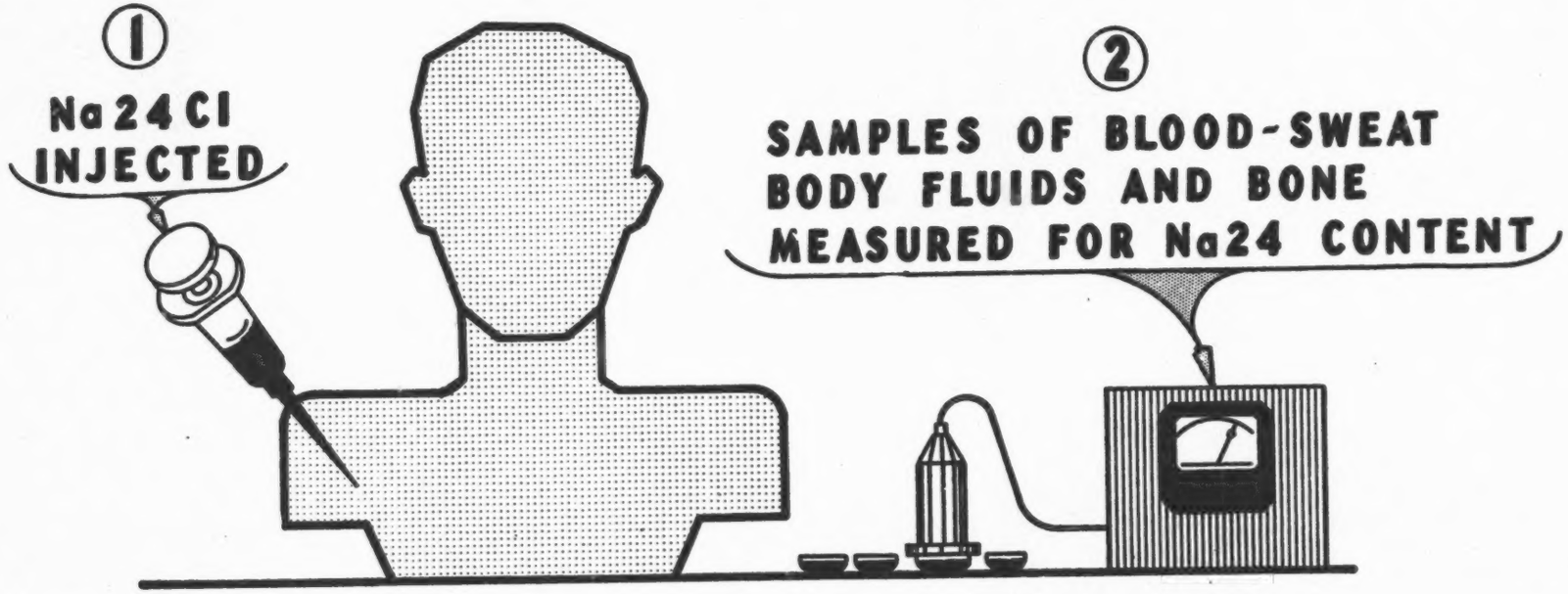
2 - LIFE SPAN OF TRANSFUSED BLOOD CELLS

3 - EFFECTIVENESS OF BLOOD PRESERVATIVE

USAEC-ID-186

RADIOACTIVE SODIUM – Na 24

FOR STUDYING SODIUM TURNOVER IN BODY



SHOWS:

RATES OF SODIUM TRANSFER THRU BLOOD VESSEL WALLS

1 - FAST { TO TISSUE FLUIDS - 50 lbs. SALT PER DAY
TO SWEAT IN 75 SECONDS

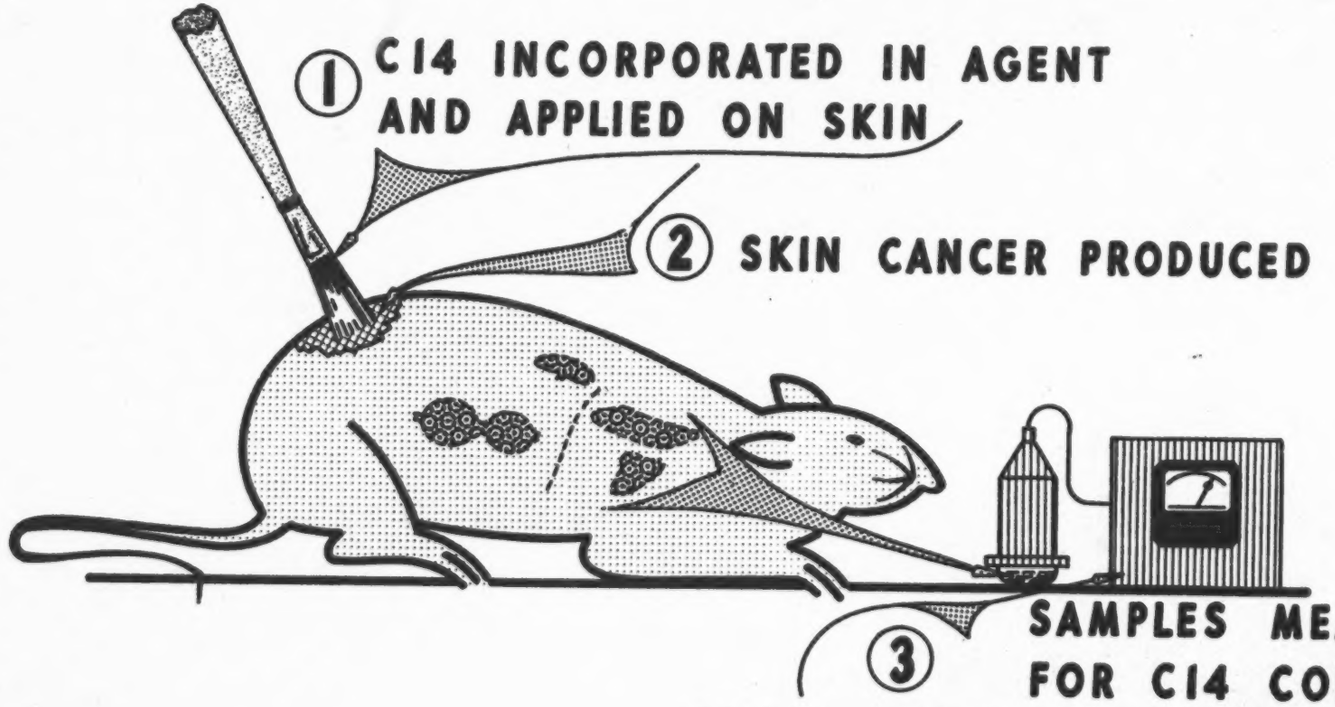
2 - MEDIUM - TO FLUID OF EYE - BRAIN - SPINAL CORD

3 - SLOW - TO BONES AND TEETH

USAEC-ID-188

RADIOACTIVE CARBON – C14

FOR STUDYING CANCER PRODUCING AGENTS - CARCINOGENS



SHOWS:

1 - AMOUNT OF AGENT IN CANCER AND OTHER TISSUE

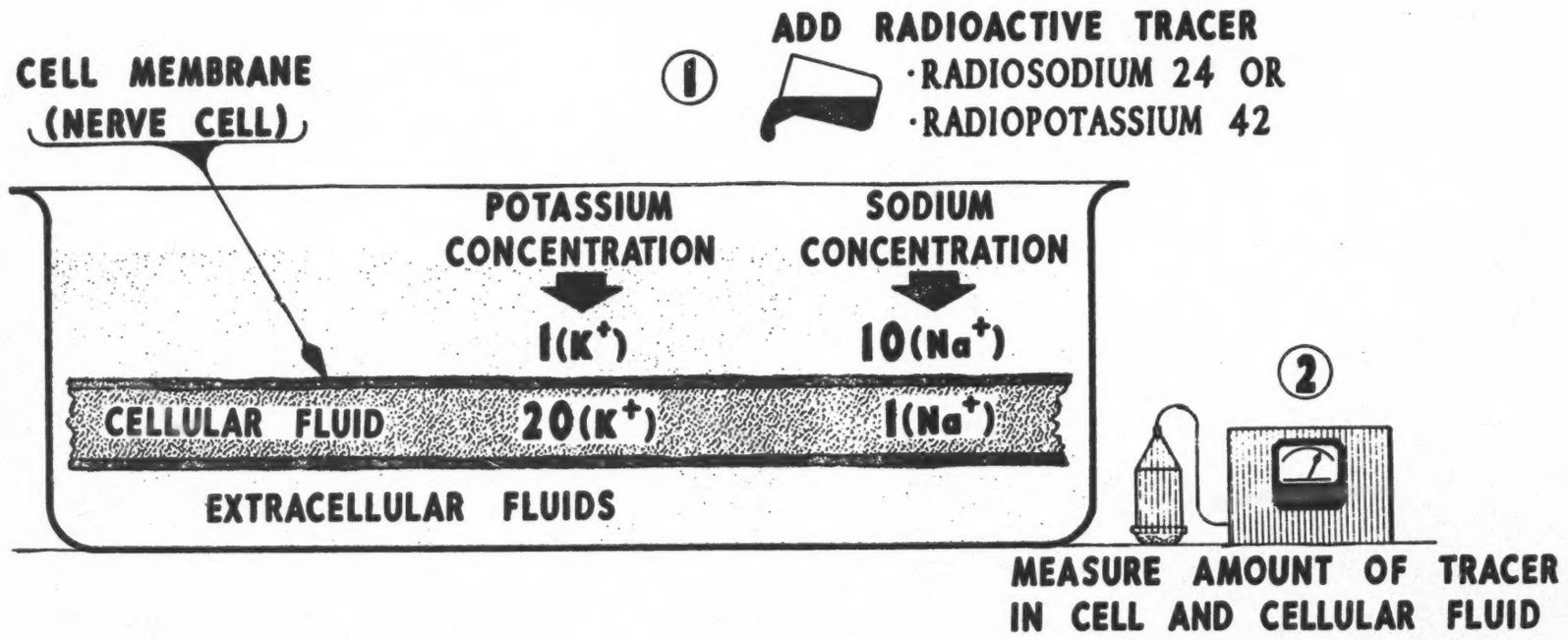
2 - LOCATION OF BREAKDOWN PRODUCTS OF THE AGENT

3 - MODE OF ACTION OF CANCER PRODUCING AGENT

USAEC-ID-189

RADIOACTIVE TRACERS

FOR STUDYING PERMEABILITY OF CELL MEMBRANES



SHOWS:

1 - RAPID TRANSFER OF ATOMS ACROSS CELL MEMBRANE

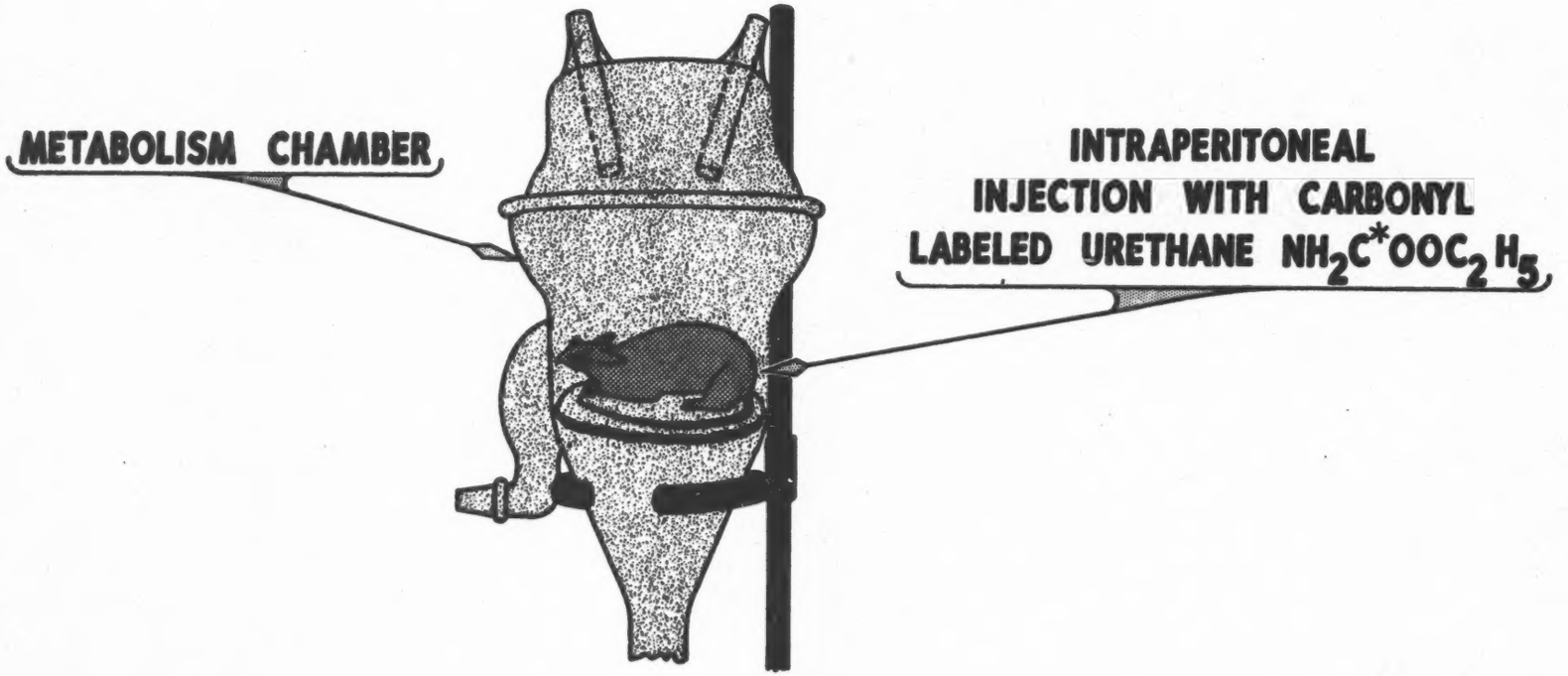
2 - TRANSFER THROUGH MEMBRANE IS COMPLICATED EXCHANGE PROCESS

3 - RATE OF TRANSFER DEPENDS ON ENZYMES AND CONDUCTION

USAEC-ID-205

RADIOACTIVE CARBON – C14

FOR STUDYING THE FATE OF AN INJECTED DRUG



SHOWS:

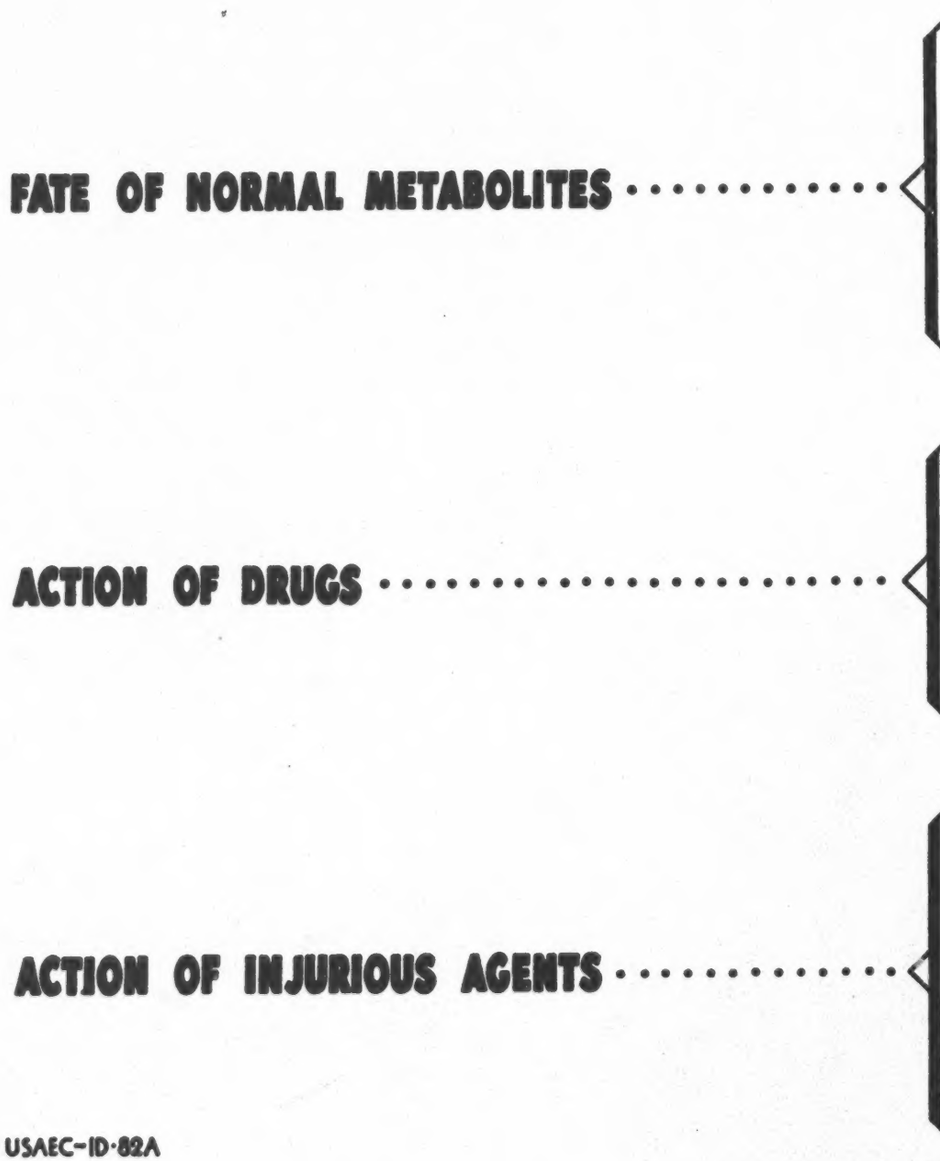
1- IN NORMAL ANIMAL 90% C14 ELIMINATED IN 24 HOURS AS C^*O_2

2- RETENTION OF C14 HIGHER IN CANCEROUS AND LEUKEMIC ANIMALS

3- SLOWER RATE OF CATABOLISM OF URETHANE IN NEOPLASTIC ANIMALS

USAEC-ID-300

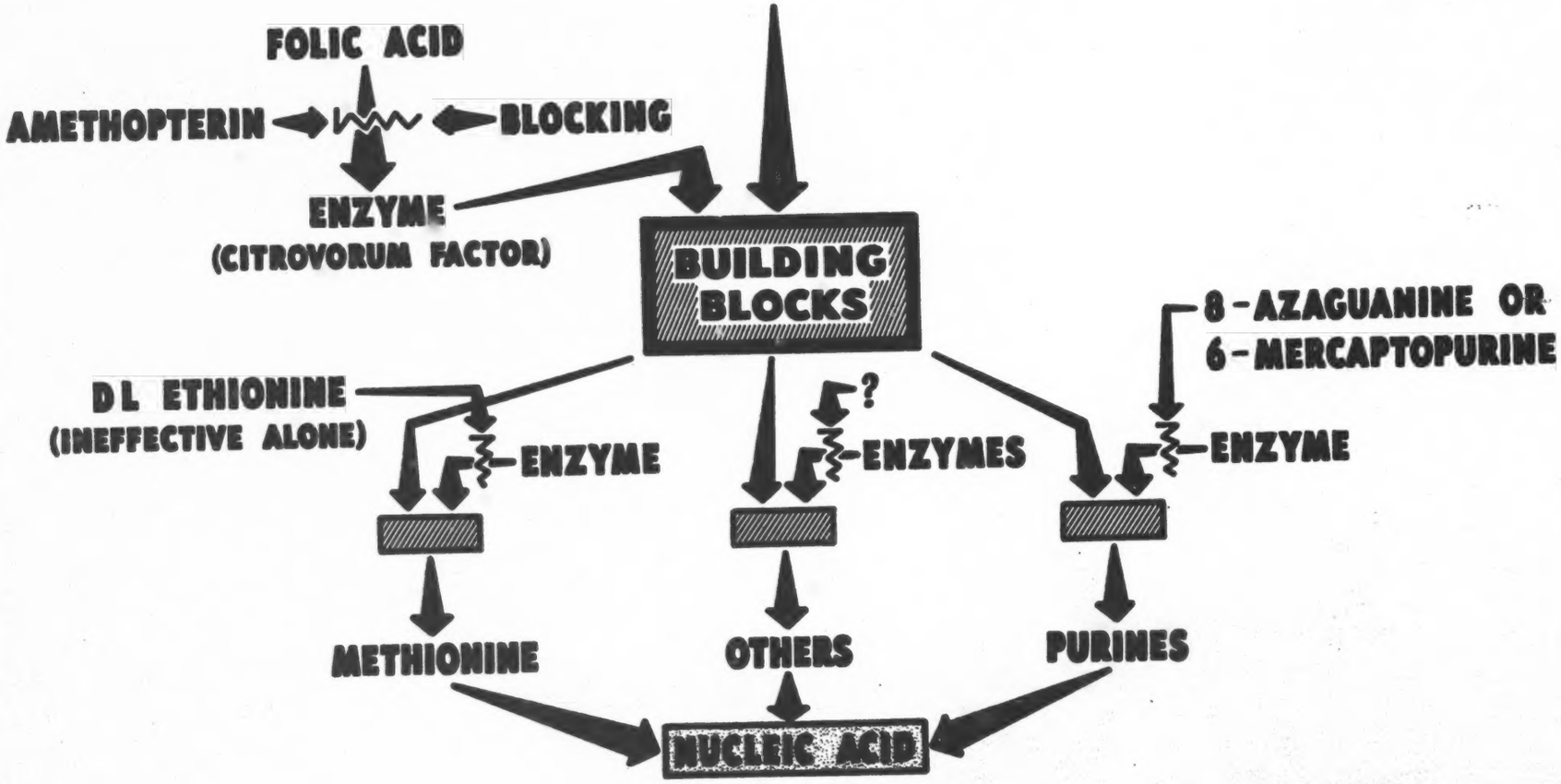
ISOTOPES FOR TRACER STUDIES IN CLINICAL RESEARCH



USAEC-ID-82A

COMBINATION BLOCKING IN CHEMOTHERAPY

SEQUENTIAL OR CONCURRENT

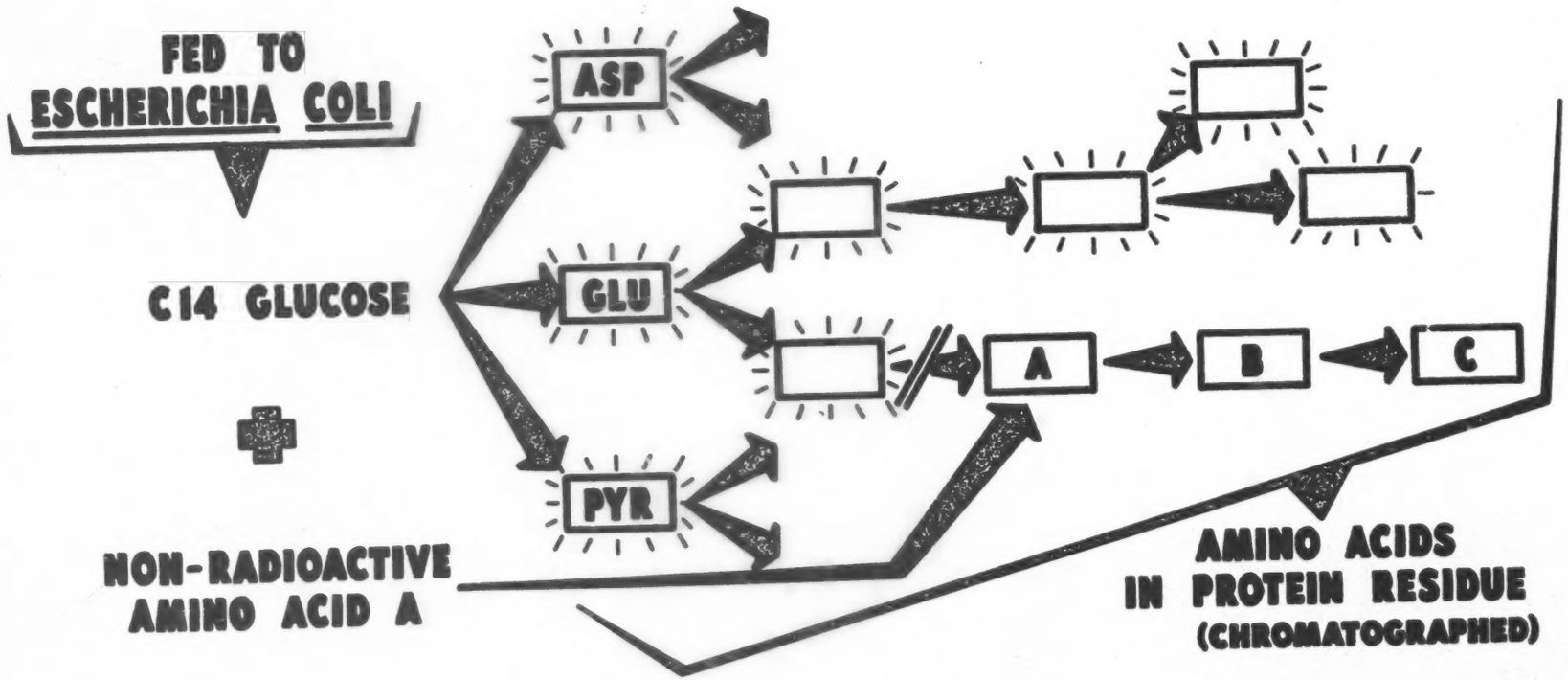


..ANTIMETABOLITE DRUGS BLOCK ESSENTIAL ENZYMES..

..COMBINATION BLOCKS SEVERAL ENZYMES — RESULTS MORE EFFECTIVE..

USAEC-ID-219A

ISOTOPIC COMPETITION METHOD
IN STUDY OF AMINO ACID PRECURSOR SCHEMES

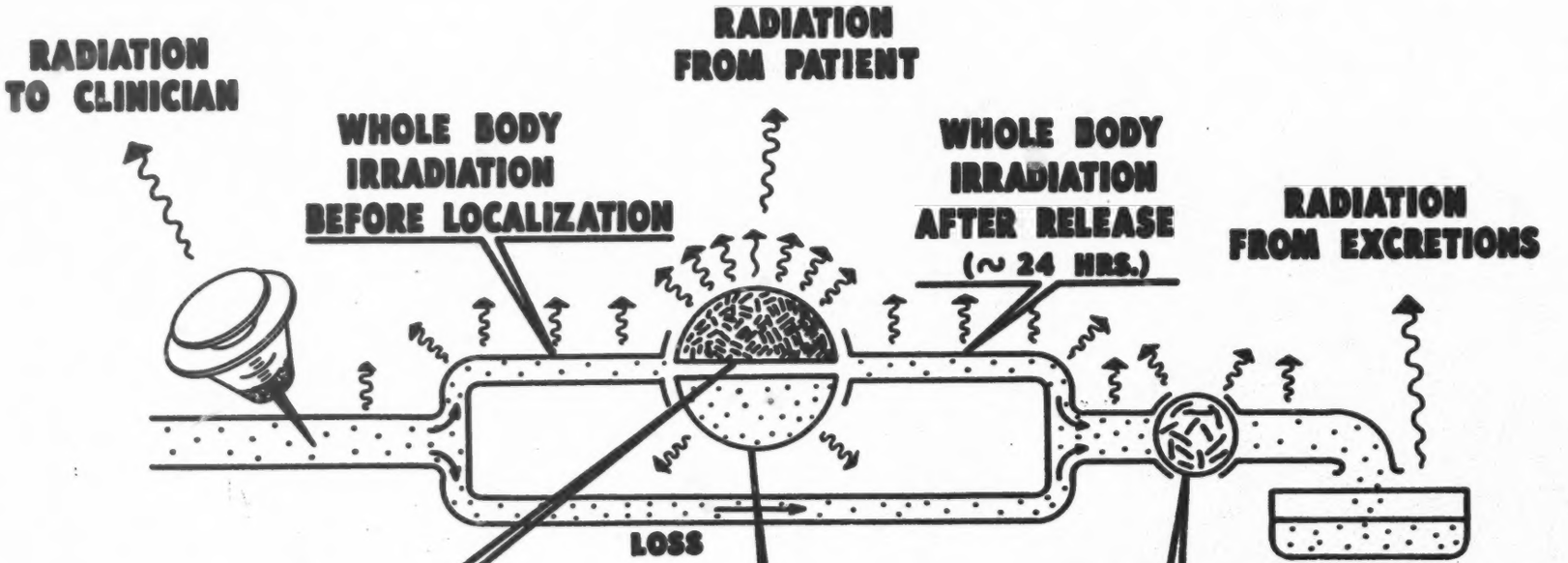


- WITHOUT ADDED (A) — RADIOACTIVITIES SHOW RELATIVE CONTENT
- ADDED (A) COMPETES SUCCESSFULLY WITH ENDOGENOUS (A)
- REDUCED ACTIVITY OF (B) AND (C) SHOWS (A) IS PRECURSOR

USAEC-ID-2204

CONSIDERATIONS IN INTERNAL USE
OF RADIOISOTOPES

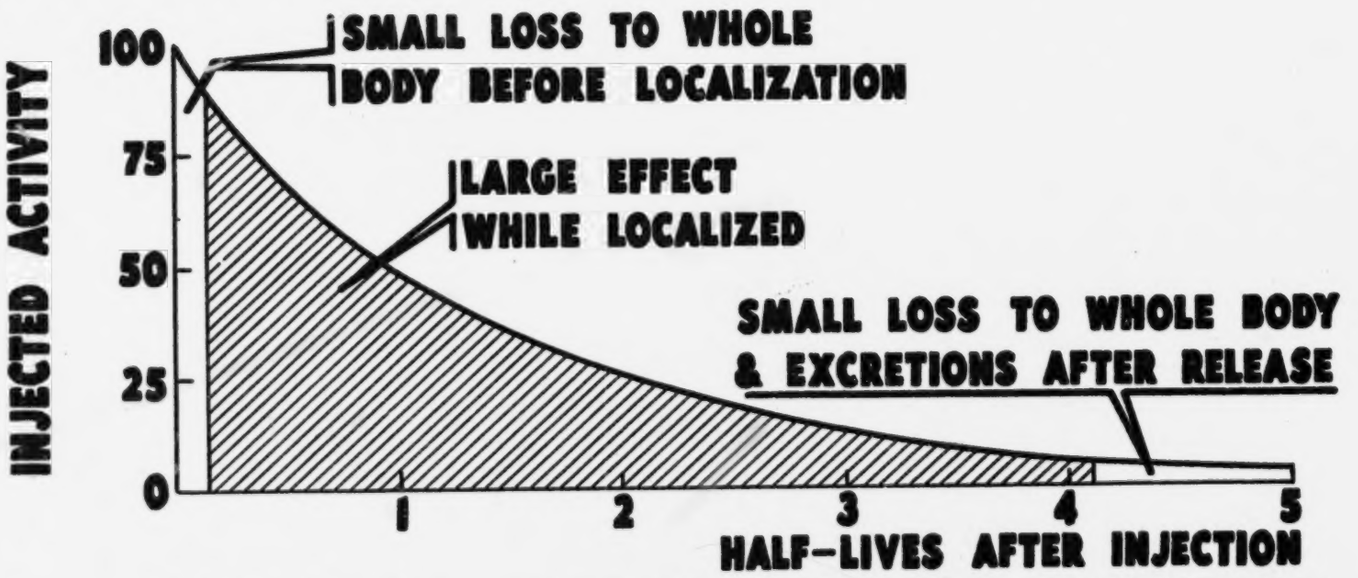
I – RADIATION HAZARDS AND COMPETITION BETWEEN TISSUES



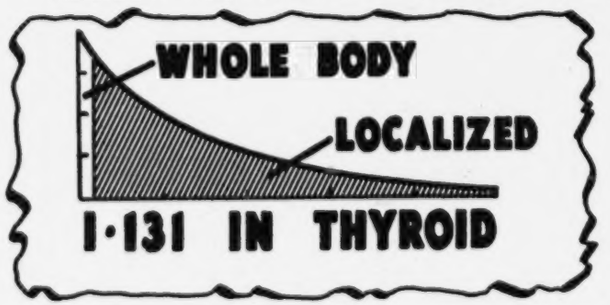
USAEC-ID·221A

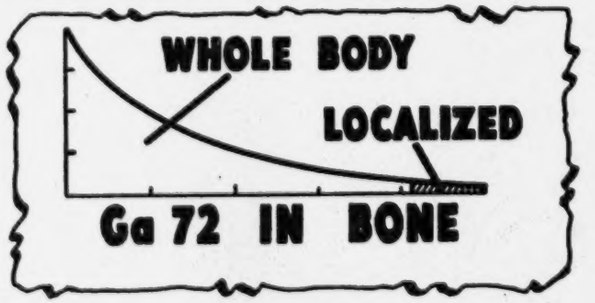
CONSIDERATIONS IN INTERNAL USE OF RADIOISOTOPES

2 – UPTAKE – RETENTION – DECAY TIMES



IDEAL UPTAKE – RETENTION – HALF-LIFE COMBINATION





USAEC-ID·222A

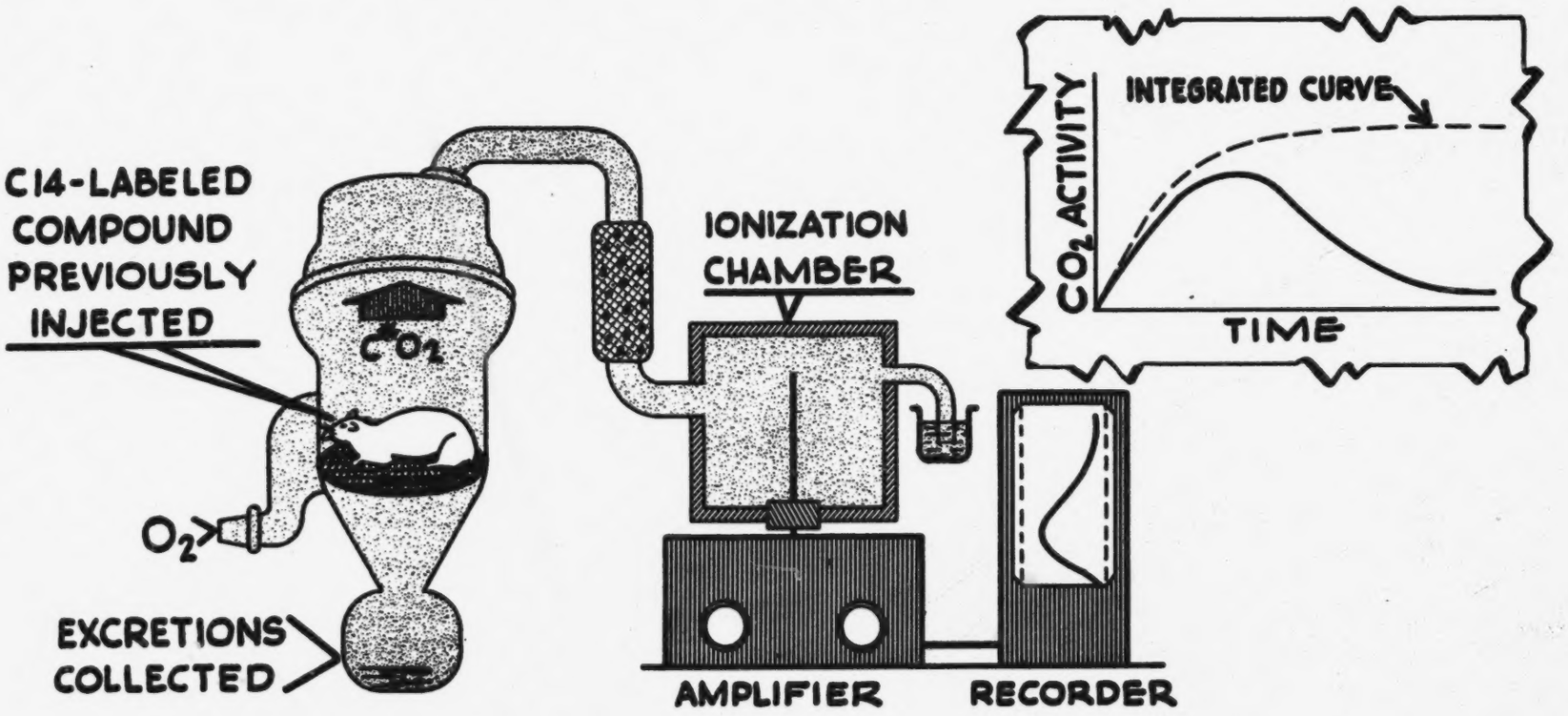
CANCER STUDIES AIDED BY RADIOISOTOPES

- CITRIC ACID CYCLE
- NUCLEIC ACID METABOLISM
- ANTICANCER DRUGS
  - ENZYME INHIBITORS
  - NITROGEN MUSTARDS
  - METABOLIC SUBSTITUTES
- SYSTEMIC EFFECTS OF CANCER
  - FUNCTIONING OF OTHER TISSUES
  - ANEMIA
- CARCINOGENS
  - RADIATION
  - AMINOAZO DYES
  - HYDROCARBONS
- INTRACELLULAR RADIATION EFFECTS

USAEC-ID-234A

Continuous Metabolic Measurement

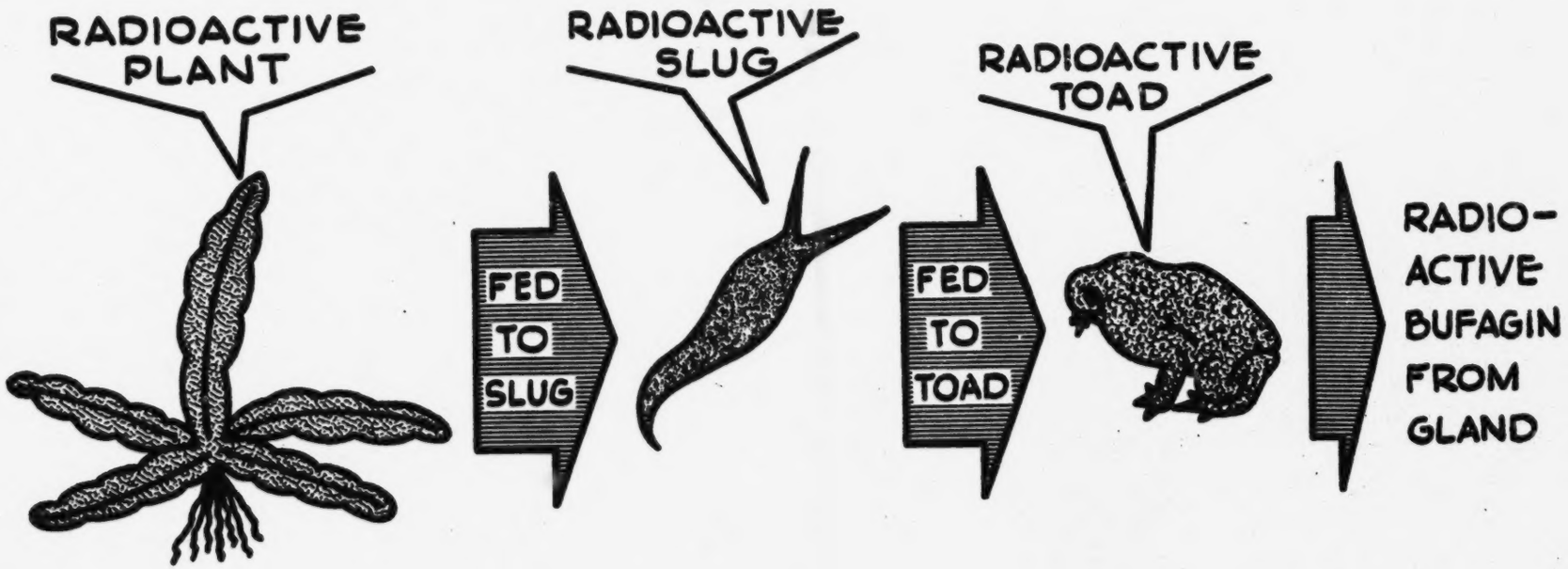
USING CARBON 14



SHOWS: 1 - CONTINUOUS RATE OF BREAKDOWN TO CO_2
2 - RAPID METABOLISM OF MOST COMPOUNDS
3 - DIFFERENCES DUE TO DRUG ACTION OR DISEASE

ID-USAEC-276A

Biological Synthesis of LABELED COMPOUNDS (BUFAGIN)

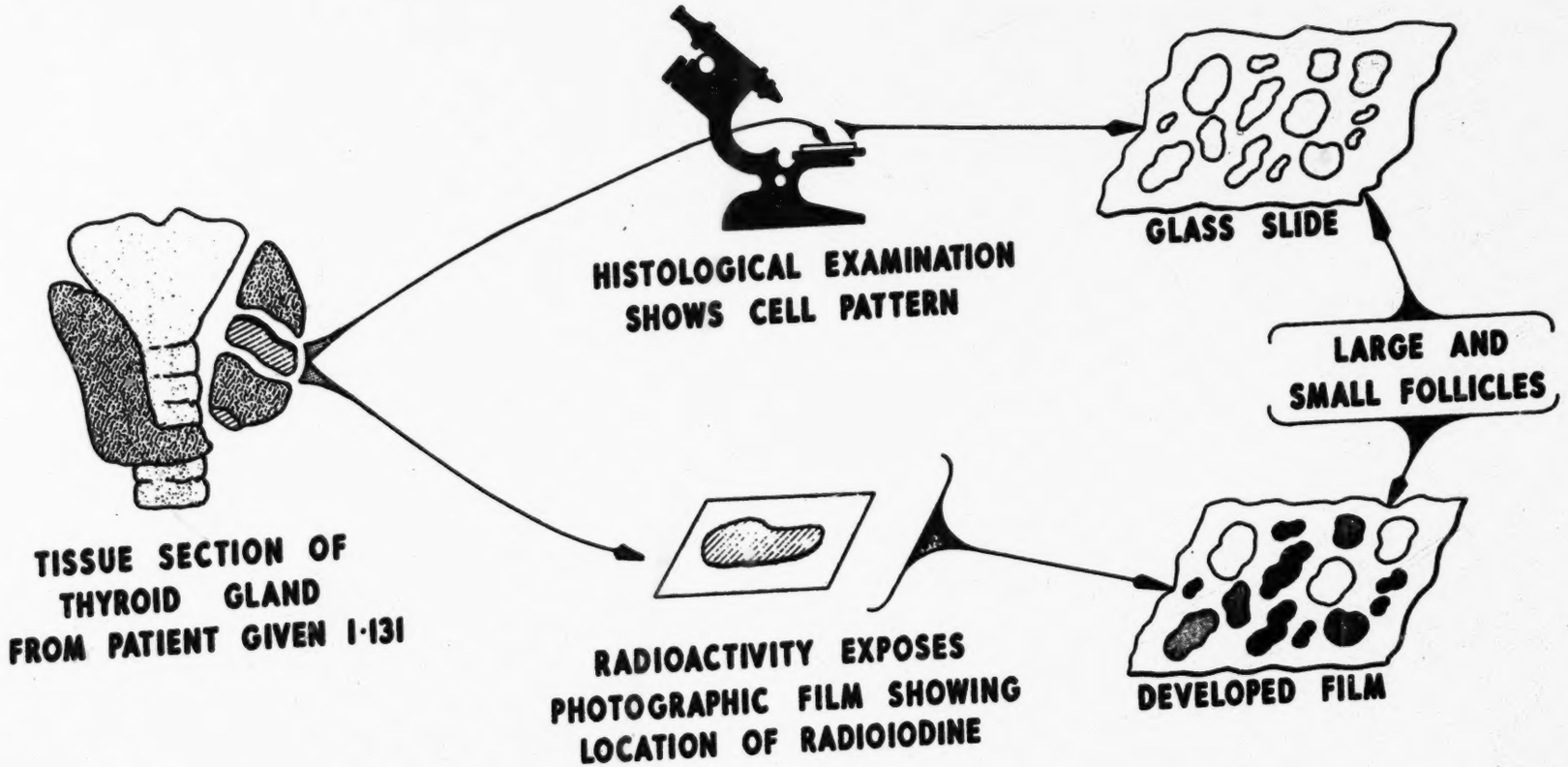


- SECRETION FROM TOAD (BUFAGIN) USED FOR TREATMENT OF HEART DISEASE.
- RADIOACTIVE BUFAGIN USED TO STUDY ACTION OF THIS DRUG.

USAEC-ID-2854

RADIOACTIVE IODINE – I·131

FOR AUTORADIOGRAPHIC EXAMINATION OF THYROID GLAND



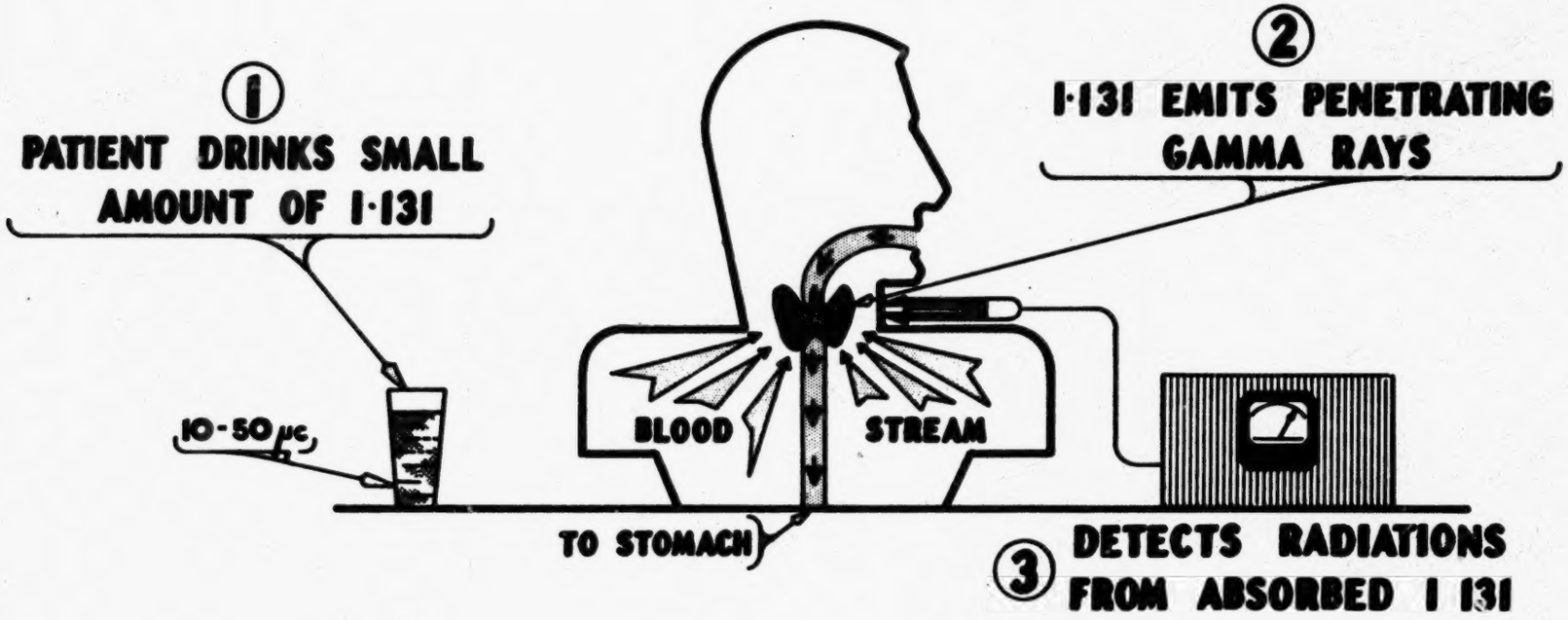
SHOWS:

1 - IODINE TAKEN UP BY FOLLICLES OF THYROID GLAND
2 - SMALL FOLLICLES CONCENTRATE I·131 MORE RAPIDLY
3 - GREATER UPTAKE IN ACIDOPHILIC THAN BASOPHILIC FOLLICLES

USAEC-ID·313A

RADIOACTIVE IODINE – I·131

FOR STUDYING THYROID GLAND PHYSIOLOGY



SHOWS:

1 - THYROID GLAND TAKES UP MOST RADIOIODINE RETAINED BY BODY

2 - IODINE ABSORPTION PROPORTIONAL TO PRODUCTION OF THYROXINE

3 - RELATIVE ABSORPTION SHOWS PHYSIOLOGICAL ACTIVITY OF GLAND

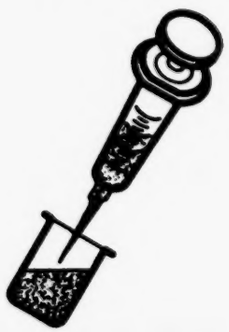
ID-USAEC

STUDY OF IRON PHYSIOLOGY

WITH

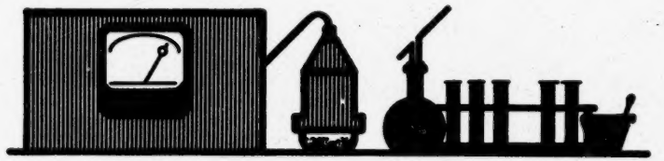
RADIOACTIVE IRON Fe59

① Fe Cl_3 ADDED TO PATIENT'S PLASMA



② LABELED PLASMA INJECTED AND BLOOD SAMPLES REMOVED AT TIMED INTERVALS

③ TOTAL IRON AND Fe59 DETERMINED IN PLASMA ALIQUOTS



SHOWS PLASMA IRON TURNOVER TO BE:

1—SENSITIVE INDICATOR OF IRON METABOLISM

2—ABOUT 1.5 TIMES AMOUNT NEEDED FOR RENEWAL OF RED CELL IRON

3—INCREASED IN POLYCYTHEMIA, LEUKEMIA AND ANEMIA

4—REDUCED IN POLYCYTHEMIA BY RADIOISOTOPE THERAPY

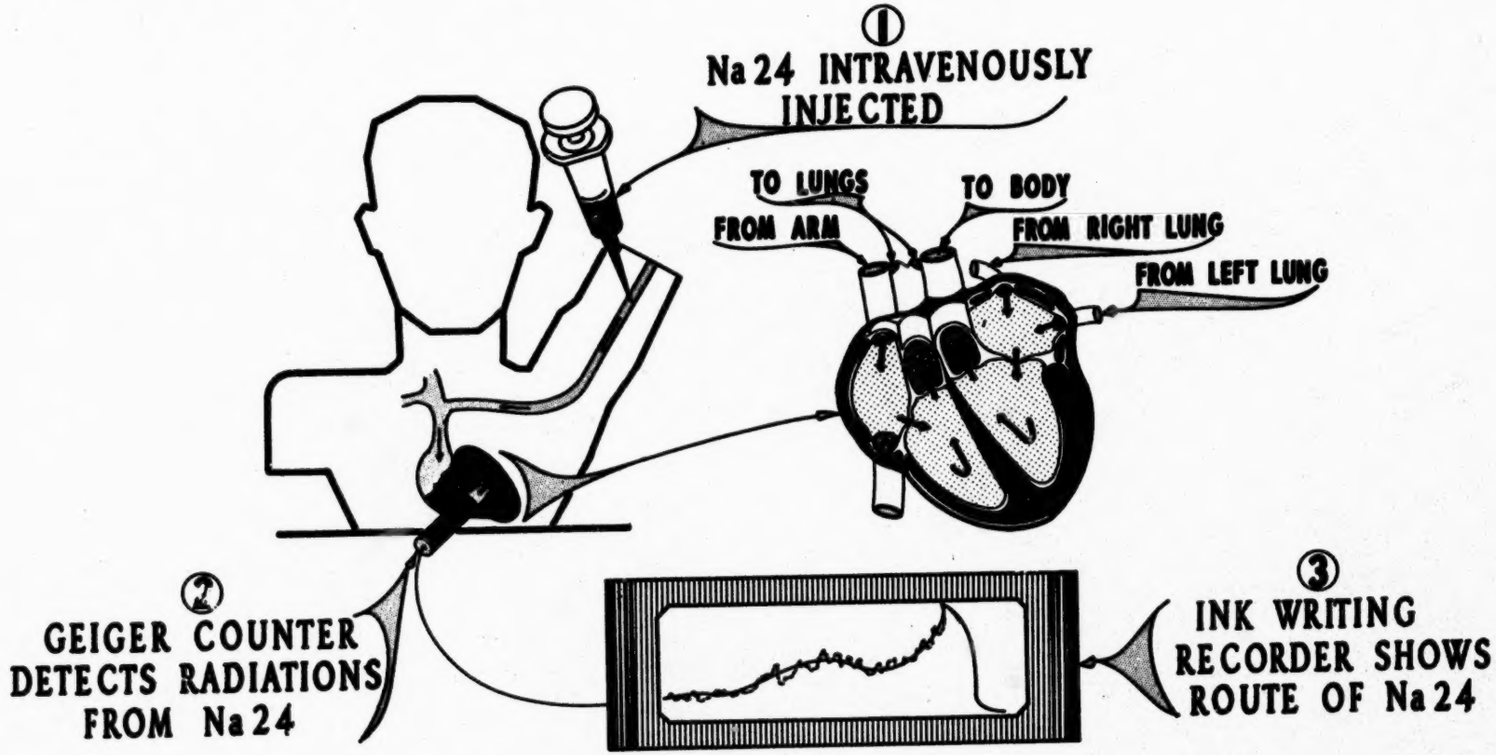
USAEC-ID 90A

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

ILLUSTRATIONS OF ISOTOPE APPLICATIONS IN BIOLOGY AND MEDICINE, DIAGNOSIS

RADIOACTIVE SODIUM Na 24

FOR DIAGNOSIS OF PUMPING QUALITIES OF HEART - RADIOCARDIOGRAPHY



ADVANTAGES:

1- GIVES INFORMATION NOT OBTAINABLE BY OTHER MEANS

2- RAPIDITY OF DIAGNOSIS - 1 TO 2 MINUTES

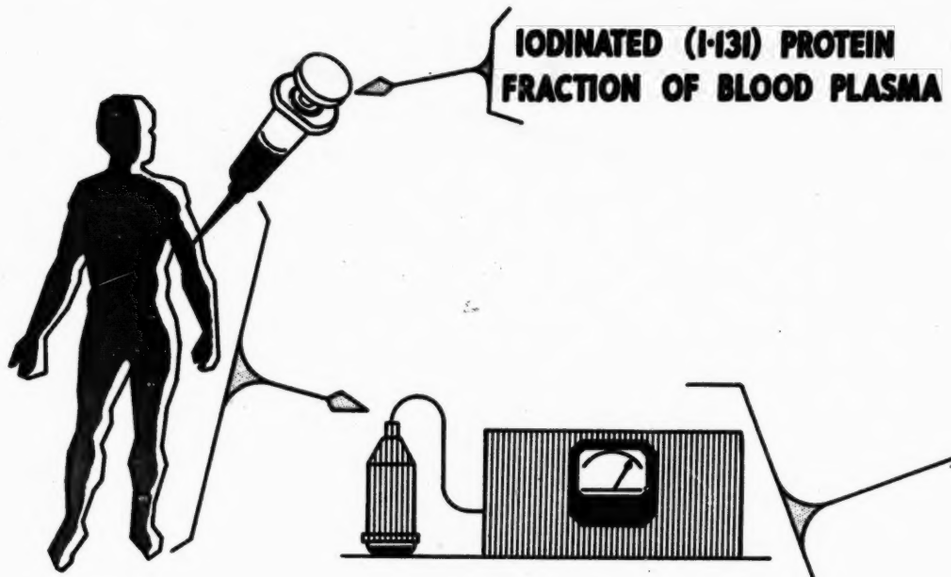
3- RADIOISOTOPE RAPIDLY ELIMINATED FROM BODY

4- NO DISCOMFORT TO PATIENT

USAEC-ID-164

RADIOACTIVE IODINE – I·131

FOR DETERMINING BLOOD PLASMA VOLUME



① KNOWN AMOUNT OF LABELED PLASMA PROTEIN INTRAVENOUSLY INJECTED

② RADIOACTIVITY OF SAMPLE OF CIRCULATING PLASMA COMPARED WITH STANDARD

③ PLASMA VOLUME

$$\frac{\text{ACTIVITY OF STANDARD/cc} \times \text{VOLUME INJECTED}}{\text{ACTIVITY OF SAMPLE/cc}}$$

ADVANTAGES:

1 - PERMITS ACCURATE PLASMA VOLUME DETERMINATIONS FOR COMPARATIVELY LONG PERIODS

2 - USED WITH HEMATOCRIT DETERMINATION GIVES QUICK AND ACCURATE BLOOD VOLUME

3 - PERMITS FOLLOWING RAPID CHANGES IN CIRCULATING BLOOD VOLUME

USAEC-ID-303

RADIOISOTOPES FOR DIAGNOSIS

ISOTOPE INDICATES FLUID SPACE OR FLOW

- BLOOD VOLUME
- BLOOD CIRCULATION TO EXTREMITIES
- RADIOCARDIOGRAPHY

ISOTOPE CONCENTRATED BY SPECIFIC TISSUE

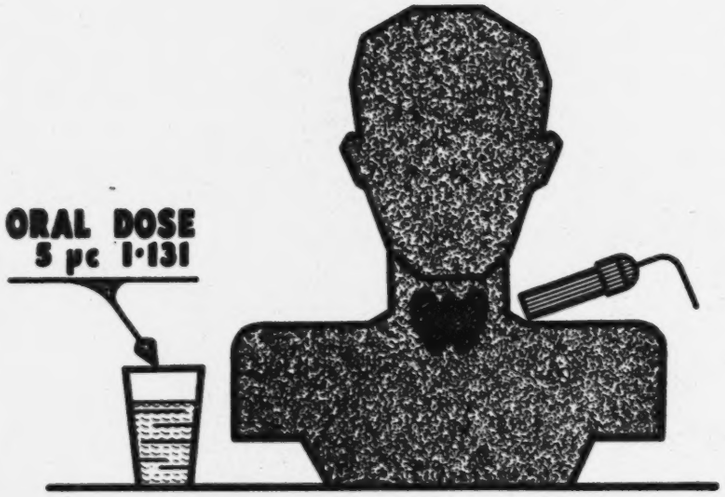
- PHYSIOLOGICAL ACTIVITY OF THYROID
- PRE-OPERATIVE LOCALIZATION OF BRAIN TUMOR
- DETERMINATION OF EXTENT OF BRAIN TUMOR

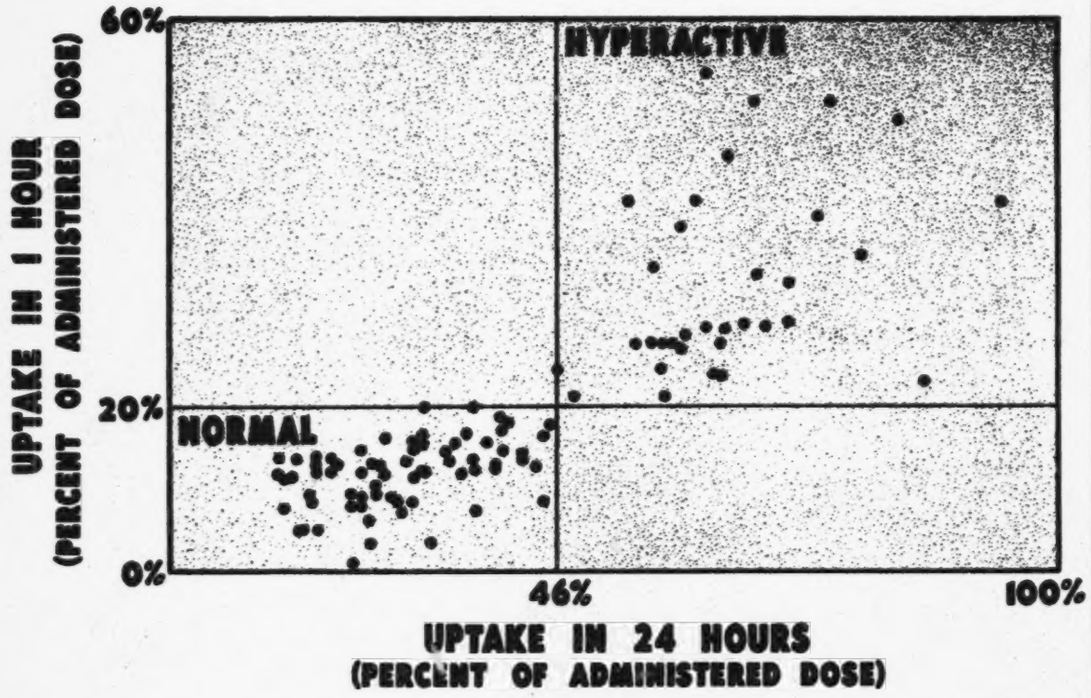
USAEC-ID-333

SCREENING TEST FOR HYPERTHYROIDISM

1 HOUR VERSUS 24 HOUR TEST

(UNIVERSITY OF VIRGINIA)





RESULTS:

1 - SCREENS HYPERTHYROID FROM NORMAL

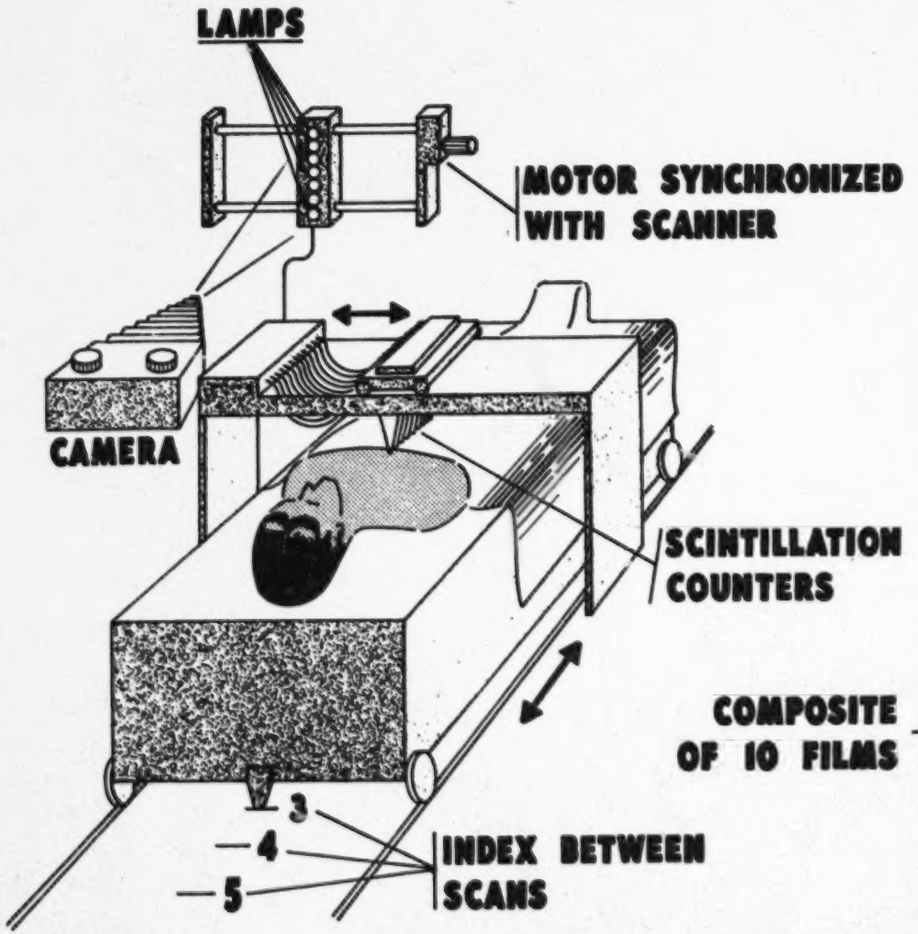
2 - SAME DIAGNOSIS AT 1 HR. AND 24 HRS. ON 128 OF 130 PATIENTS

3 - TESTS CLINICALLY CONFIRMED

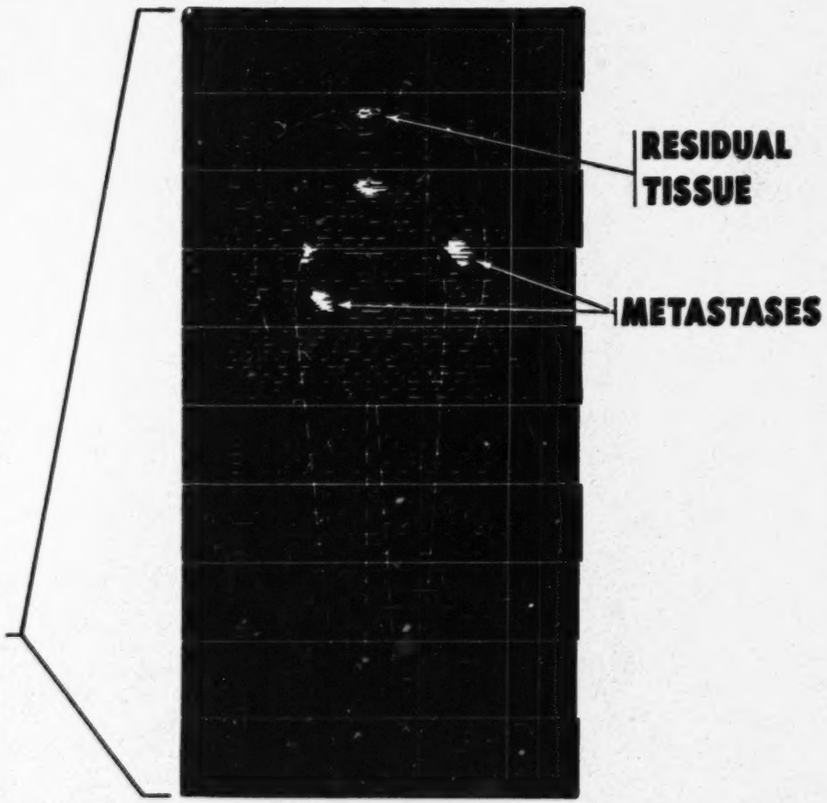
USAEC-ID-153A

WHOLE BODY SCANNING

WITH THE AID OF RADIOISOTOPES



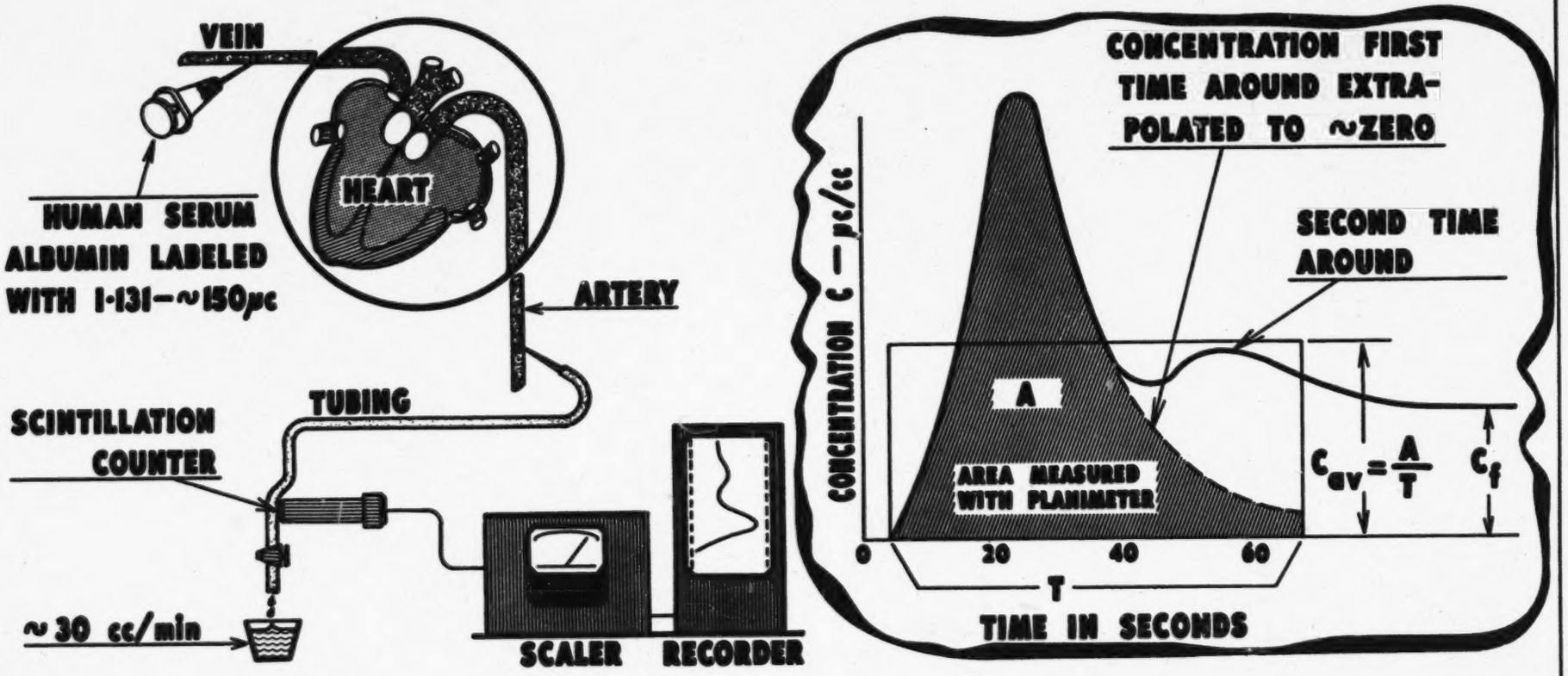
THYROIDECTOMIZED PATIENT
4 DAYS AFTER 5 mc DOSE OF I-131



USES: 1—MAPS RADIOACTIVITY LOCALIZED IN TISSUES
2—LOCATES UNSUSPECTED METASTASES
3—REVEALS RESIDUAL TISSUE AFTER OPERATION

USAEC-ID-156A

CARDIAC OUTPUT
USING
I·131 LABELED HUMAN SERUM ALBUMIN



INJECTED ACTIVITY = HEART OUTPUT DURING $T \times C_{av}$ = TOTAL BLOOD VOLUME $\times C_f$

FLOW RATE $\times T \times C_{av} = V \times C_f$

$$\text{FLOW RATE} = \frac{C_f}{C_{av}} \times \frac{V}{T} \text{ liters/min}$$

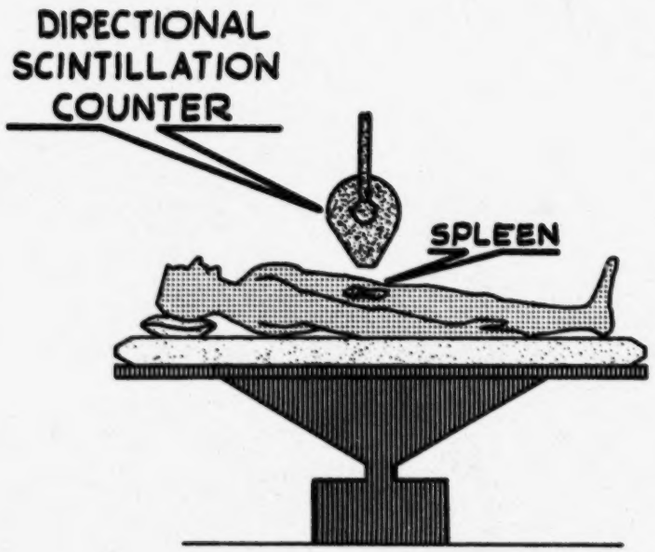
USAEC-ID·157A

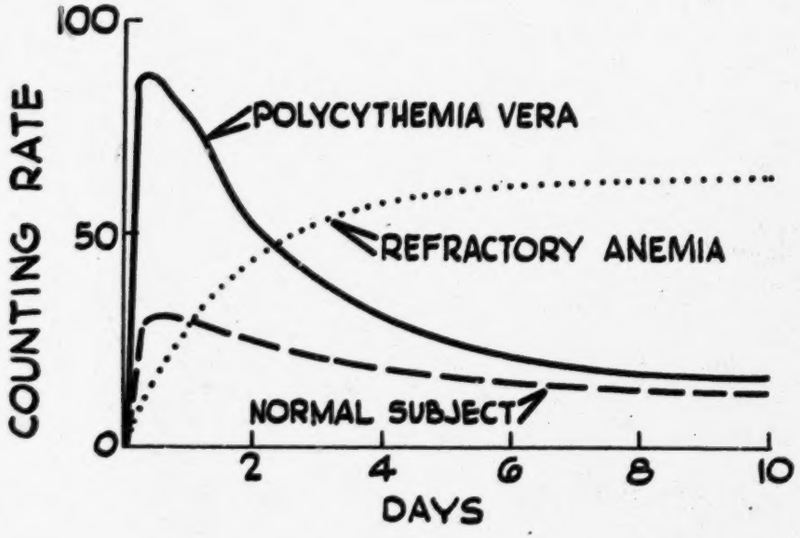
CHIEF CLINICAL USES OF RADIOISOTOPES

ISOTOPE	USE	USING INSTITUTIONS
	DIAGNOSIS	
I-131	THYROID FUNCTION (DIAGNOSIS ONLY)	80
	BLOOD VOLUME, CIRCULATION, ETC.	111
	TUMOR DETECTION (BRAIN, LIVER, ETC.)	95
P 32	BLOOD VOLUME, CIRCULATION, ETC.	37
	TUMOR DETECTION	39
	TREATMENT	
I-131	HYPERTHYROIDISM AND HEART DISORDERS	291
	CANCER	242
P 32	POLYCYTHEMIA AND LEUKEMIA	269
	CANCER	87
Au 198	INTRACAVITARY	131
	PROSTATE	32
	OTHER INTERSTITIAL	43

USAEC-ID-204A

Uptake in Spleen
USING
RADIOACTIVE IRON

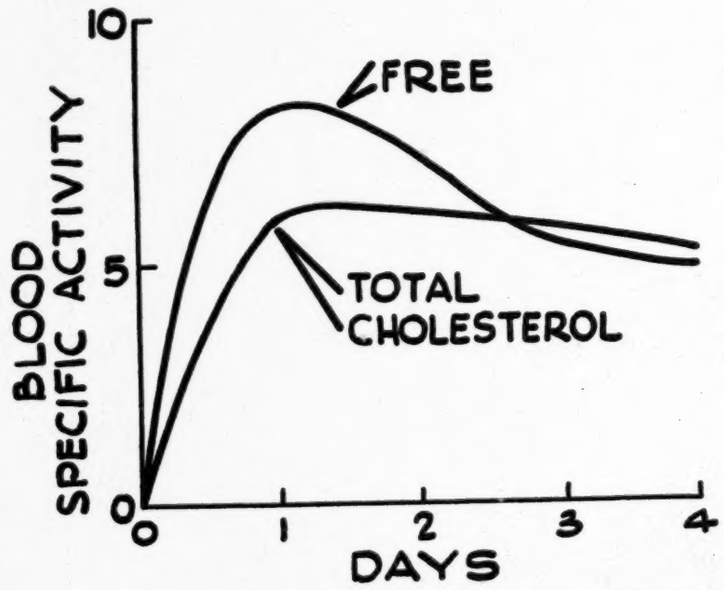




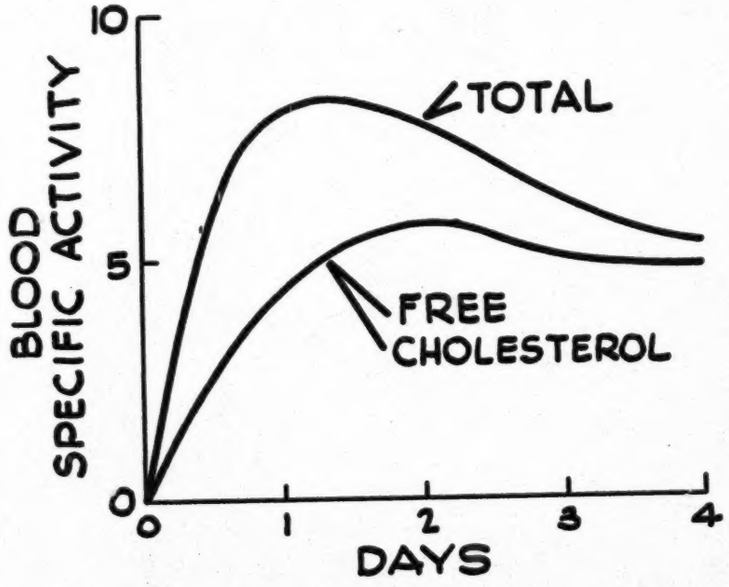
POLYCYTHEMIA VERA — INCREASED RED-CELL PRODUCTION IN SPLEEN
REFRACTORY ANEMIA — SPLEEN DESTROYS RED-CELLS AT ABNORMAL RATE
NORMAL SUBJECT — BALANCE OF PRODUCTION AND DESTRUCTION

USAEC-ID-278A

Detection of Arteriosclerosis
USING
TRITIUM-LABELED CHOLESTEROL



NORMAL SUBJECT

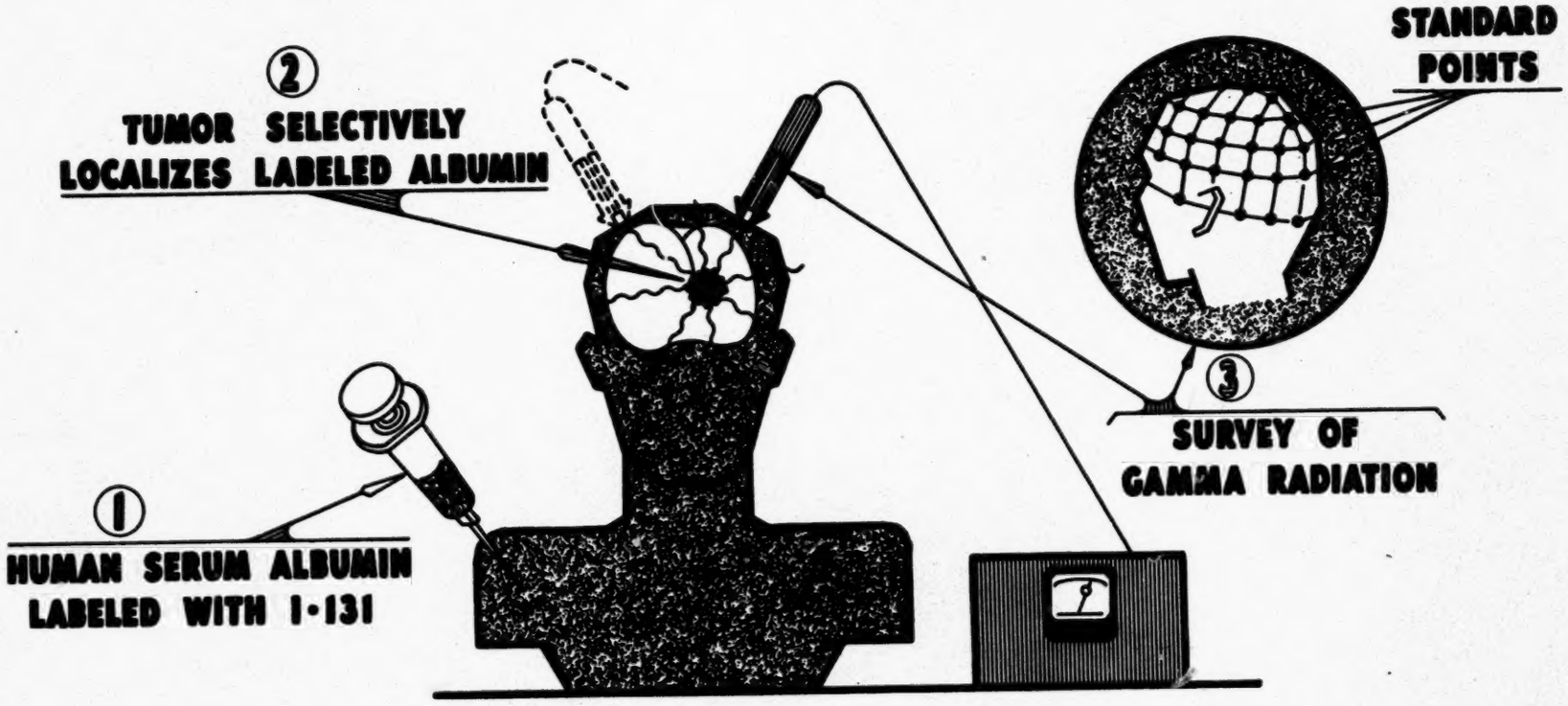


PATIENT WITH ARTERIOSCLEROSIS

..CONSTANT FINDING BETWEEN NORMAL AND DISEASED MAN.
..TEST MAY LEAD TO EARLY DIAGNOSIS OF A TENDENCY TOWARD ARTERIOSCLEROSIS.

USAEC-ID·281A

LOCATING BRAIN TUMORS
WITH
I·131–TAGGED HUMAN SERUM ALBUMIN



AID TO DIAGNOSIS PRIOR TO SURGERY

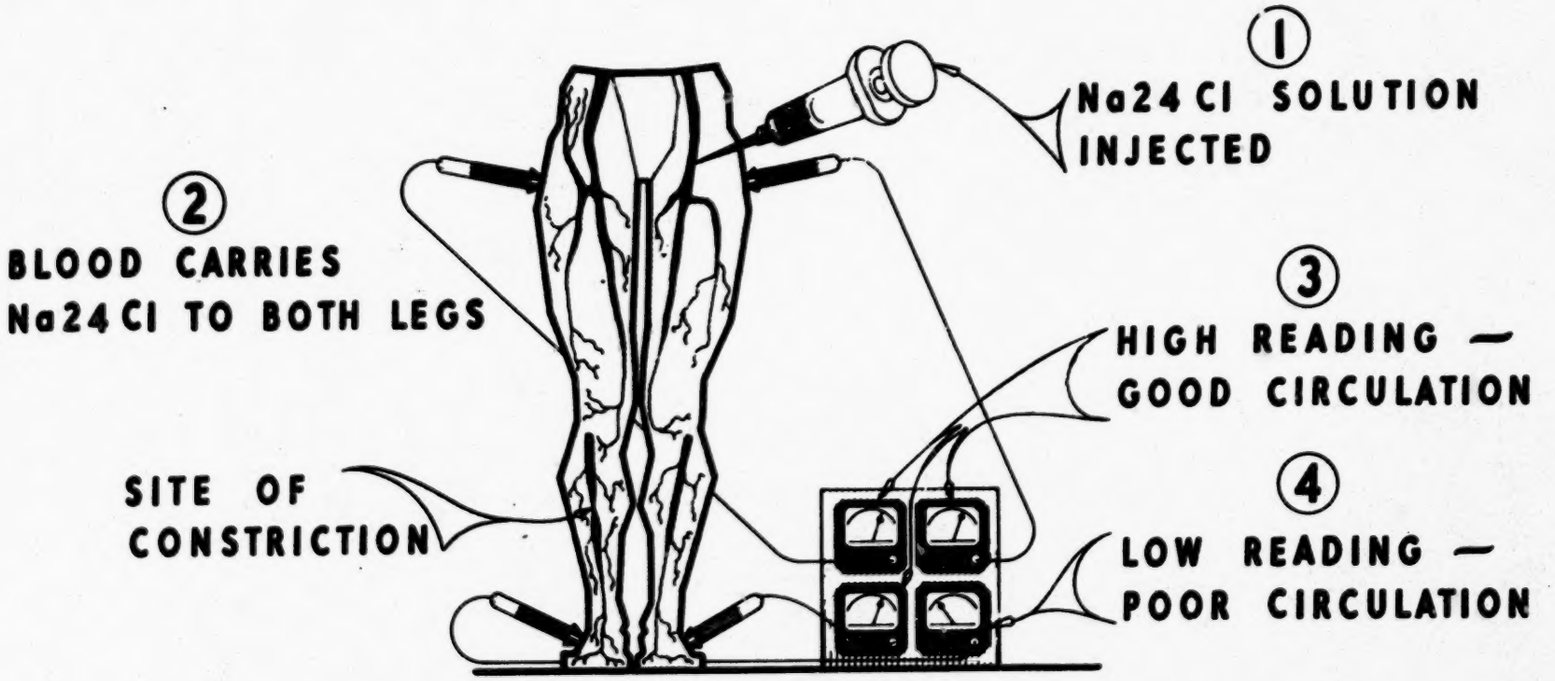
LOCATES TUMORS NOT FOUND BY OTHER MEANS

CAN USE MULTIPLE COUNTERS FIXED IN STANDARD POSITIONS

USAEC-ID·154A

RADIOACTIVE SODIUM – Na 24

FOR DETECTING NORMAL AND RESTRICTED BLOOD CIRCULATION



ADVANTAGES:

1-GIVES PATTERN OF BLOOD FLOW

2-PERMITS EXACT LOCATION OF ARTERIAL CONSTRICTION

3-METHOD QUICK AND NO DISCOMFORT TO PATIENT

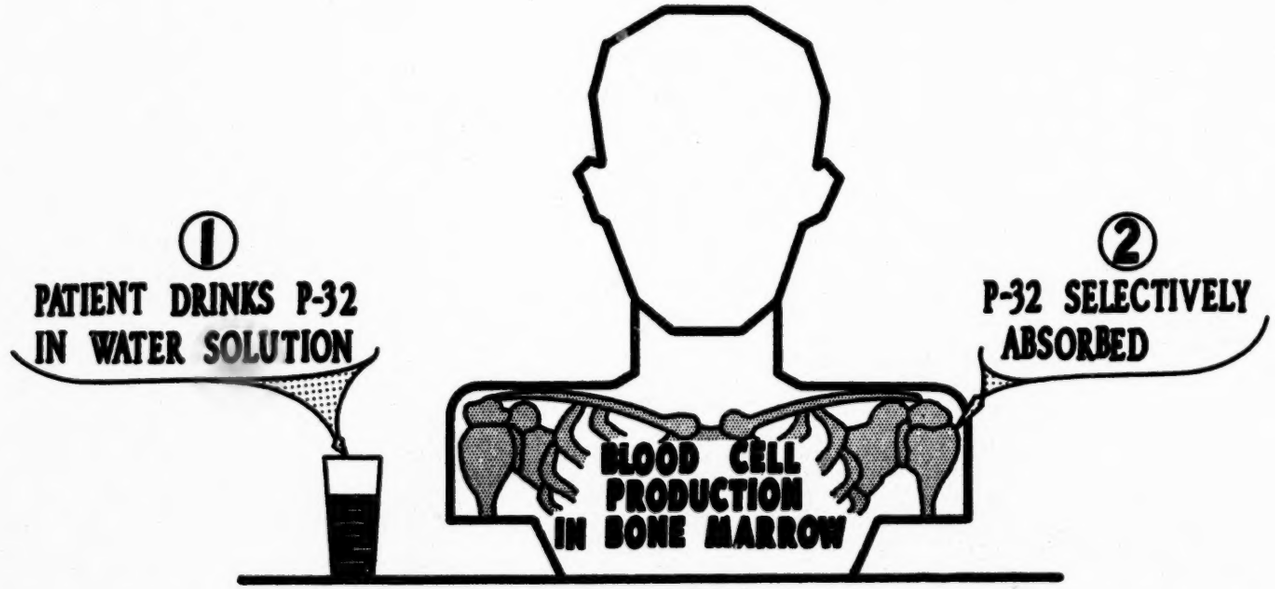
ID-USAEC

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

ILLUSTRATIONS OF ISOTOPE APPLICATIONS IN BIOLOGY AND MEDICINE, THERAPY

RADIOACTIVE PHOSPHORUS – P32

FOR TREATMENT OF: A-POLYCYTHEMIA VERA
B-CHRONIC LEUKEMIA



THERAPEUTIC ACTION:

1 - PARTIALLY SELECTIVE UPTAKE

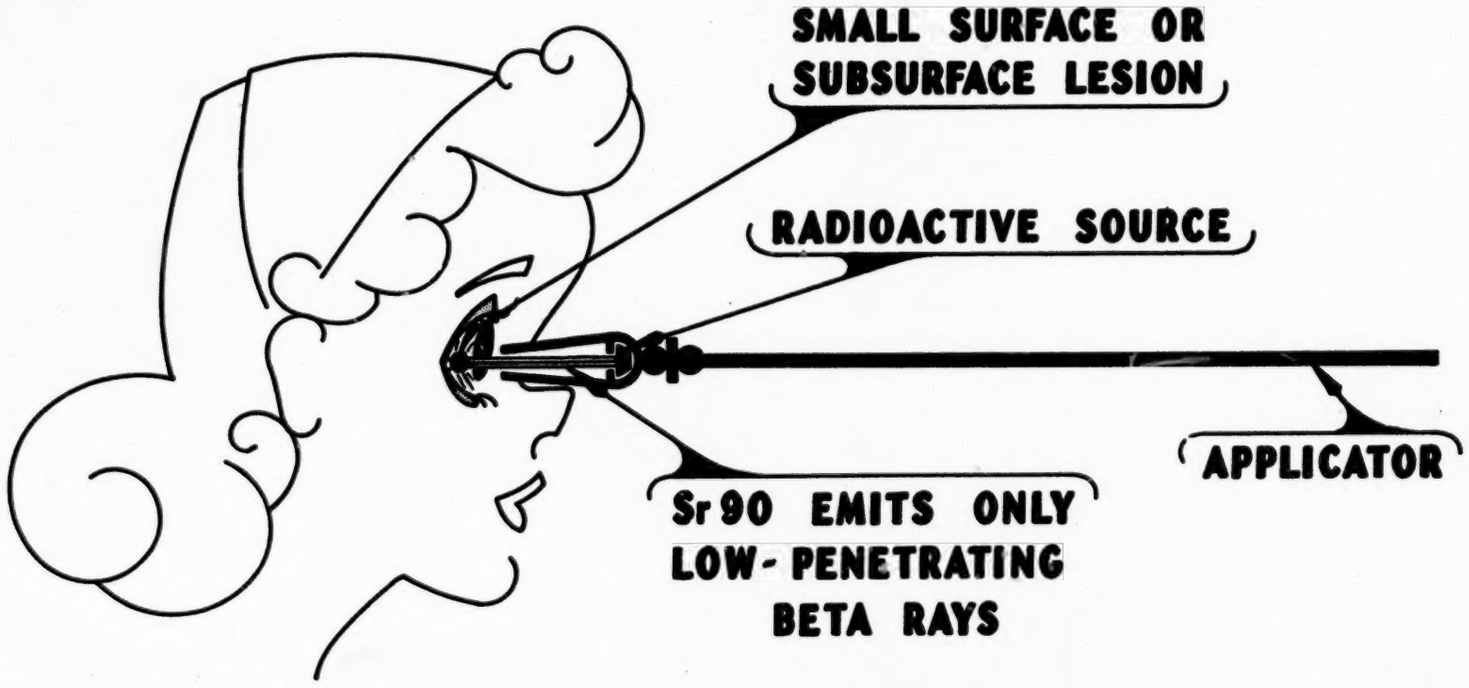
2 - SLOW PROTRACTED IRRADIATION

3 - INHIBITS BLOOD CELL PRODUCTION

USAEC-ID-191

RADIOACTIVE STRONTIUM – Sr 90

FOR TREATING SMALL LESIONS



ADVANTAGES:

1 - NO EXTRANEOUS GAMMA RADIATION

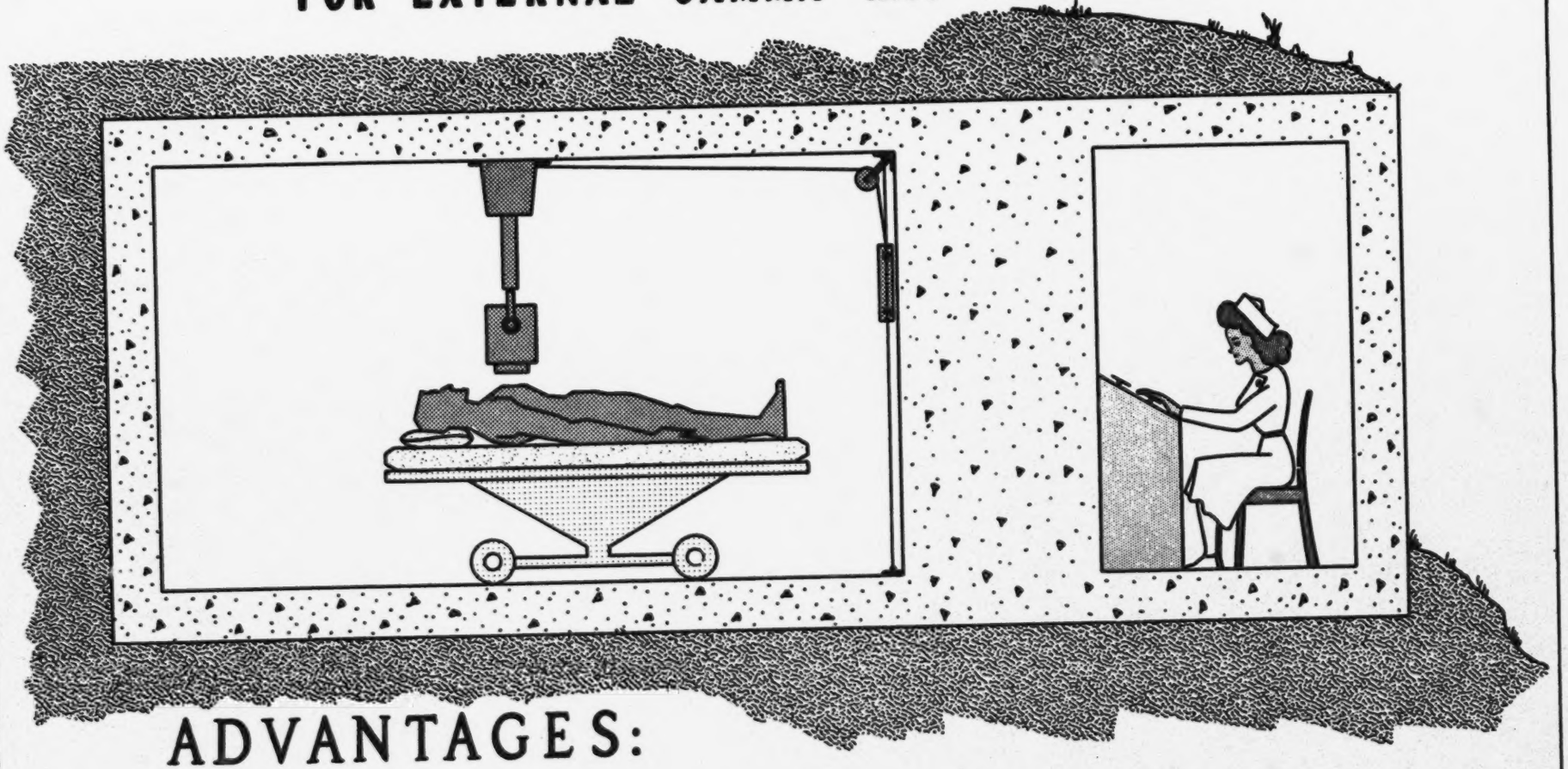
2 - REMOVAL OF BENIGN TUMORS WITHOUT SURGERY

3 - READILY ADAPTABLE TO THERAPY OF POSTOPERATIVE LESIONS

USAEC-ID-200

RADIOACTIVE COBALT – Co 60

FOR EXTERNAL GAMMA RAY TREATMENT



ADVANTAGES:

1 - HIGHLY PENETRATING RADIATION

2 - RADIATION ENERGY NEARLY UNIFORM

3 - INEXPENSIVE TO PRODUCE

USAEC-ID·306

ADVANTAGES OF RADIOCOBALT FOR INTERSTITIAL TREATMENT

PERMITS TECHNIQUES BASED ON:

A. THIN WALL TUBING TO REMOVE BETA RAYS

1 - STAINLESS STEEL - - 0.1 mm.
2 - ALUMINUM - - 0.3 mm.
3 - NYLON - - 0.7 mm.

B. LARGE INVENTORY OF RADIOCOBALT

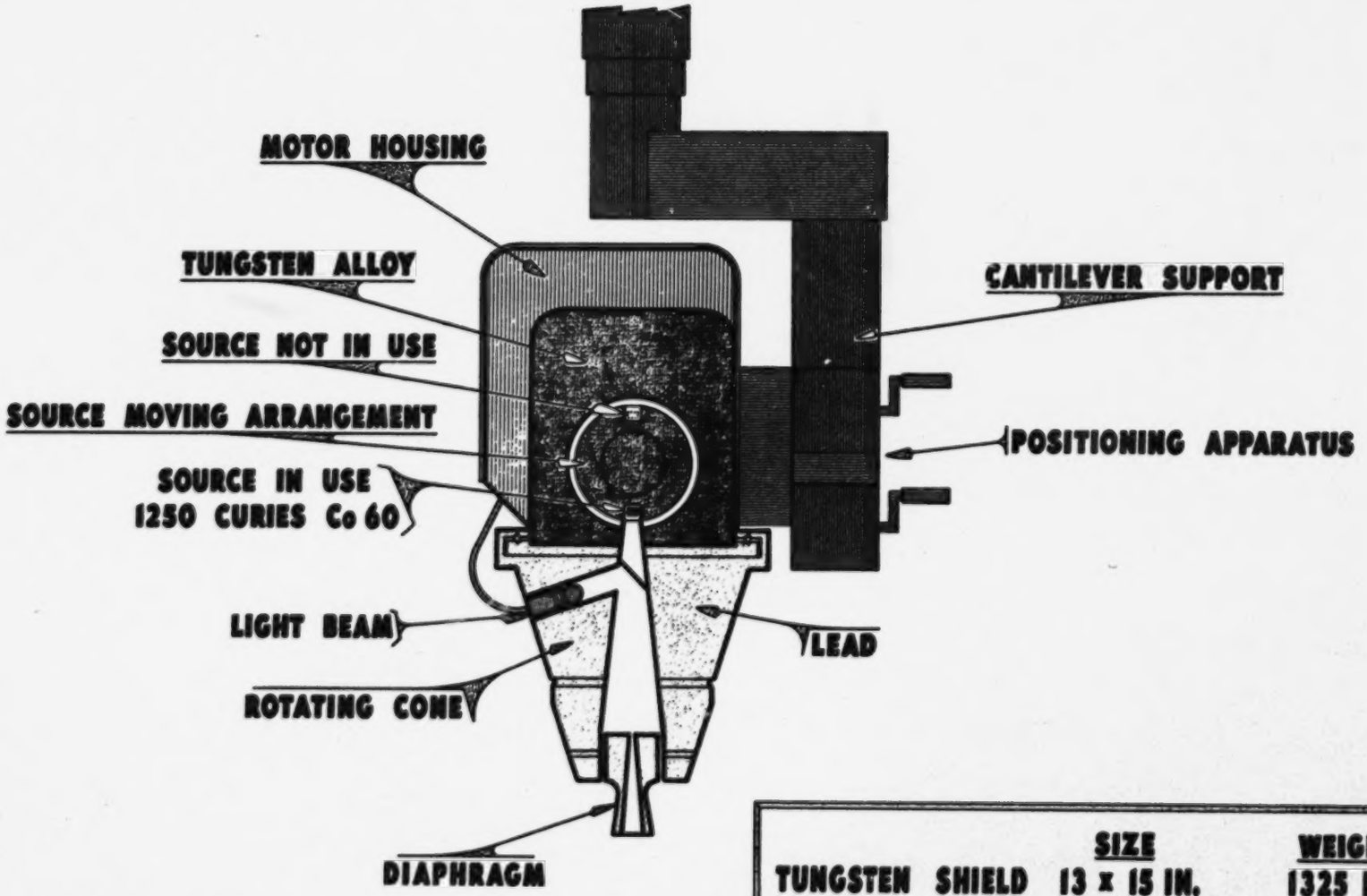
1 - AVAILABLE IN LARGE QUANTITIES AT LOW COST
2 - AVAILABLE IN WIDE RANGE OF ACTIVITIES PER GRAM
3 - SPECIAL APPLICATORS STOCKED FOR VARIETY OF CASE TYPES

C. NEEDLES AND SHEATHS EASILY TAILORED FOR EACH CASE

1 - TUBING EASILY LOADED AND SHAPED
2 - DISTRIBUTION OF ACTIVITY VARIED AS DESIRED
3 - COBALT READILY RECOVERED - - TUBING EXPENDABLE

USAEC-ID-390

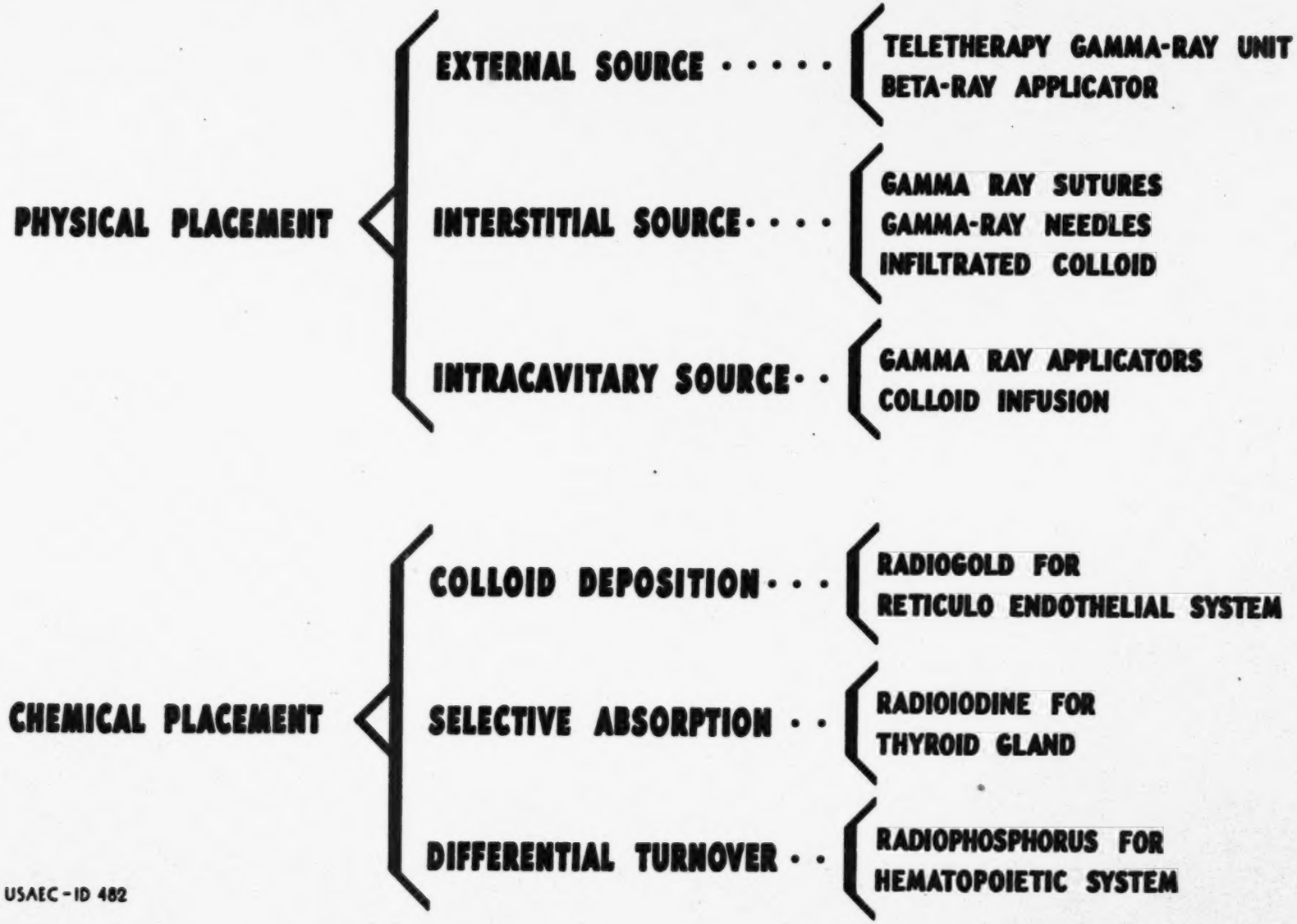
GAMMA RAY TELETHERAPY UNIT



	SIZE	WEIGHT
TUNGSTEN SHIELD	13 x 15 IN.	1325 LBS.
CONE	13 x 15 IN.	300 LBS.
DIAPHRAGMS	15 x 15 cm MAX.	25-50 LBS.

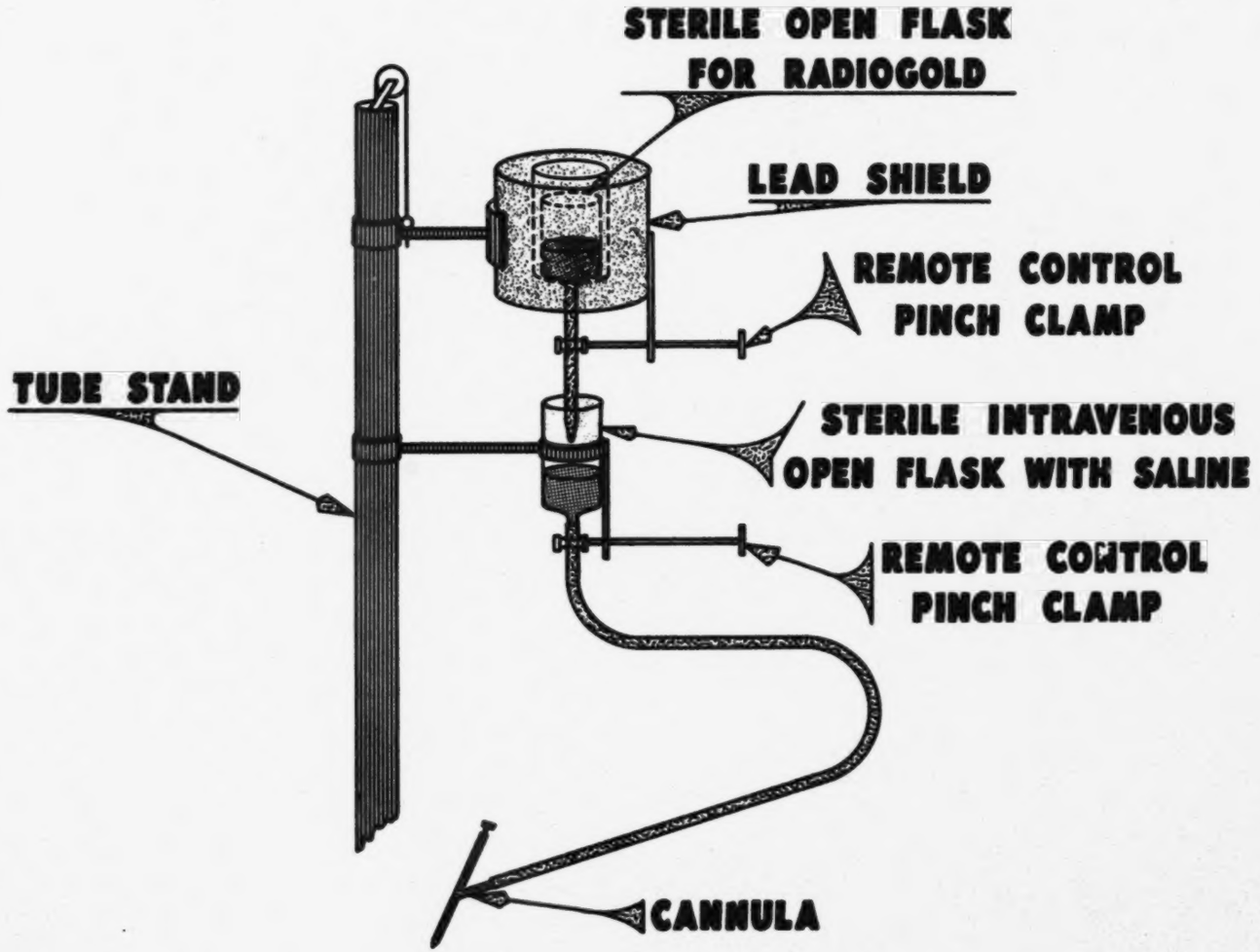
USAEC - ID 481

THERAPY METHODS WITH RADIOISOTOPES



USAEC - ID 482

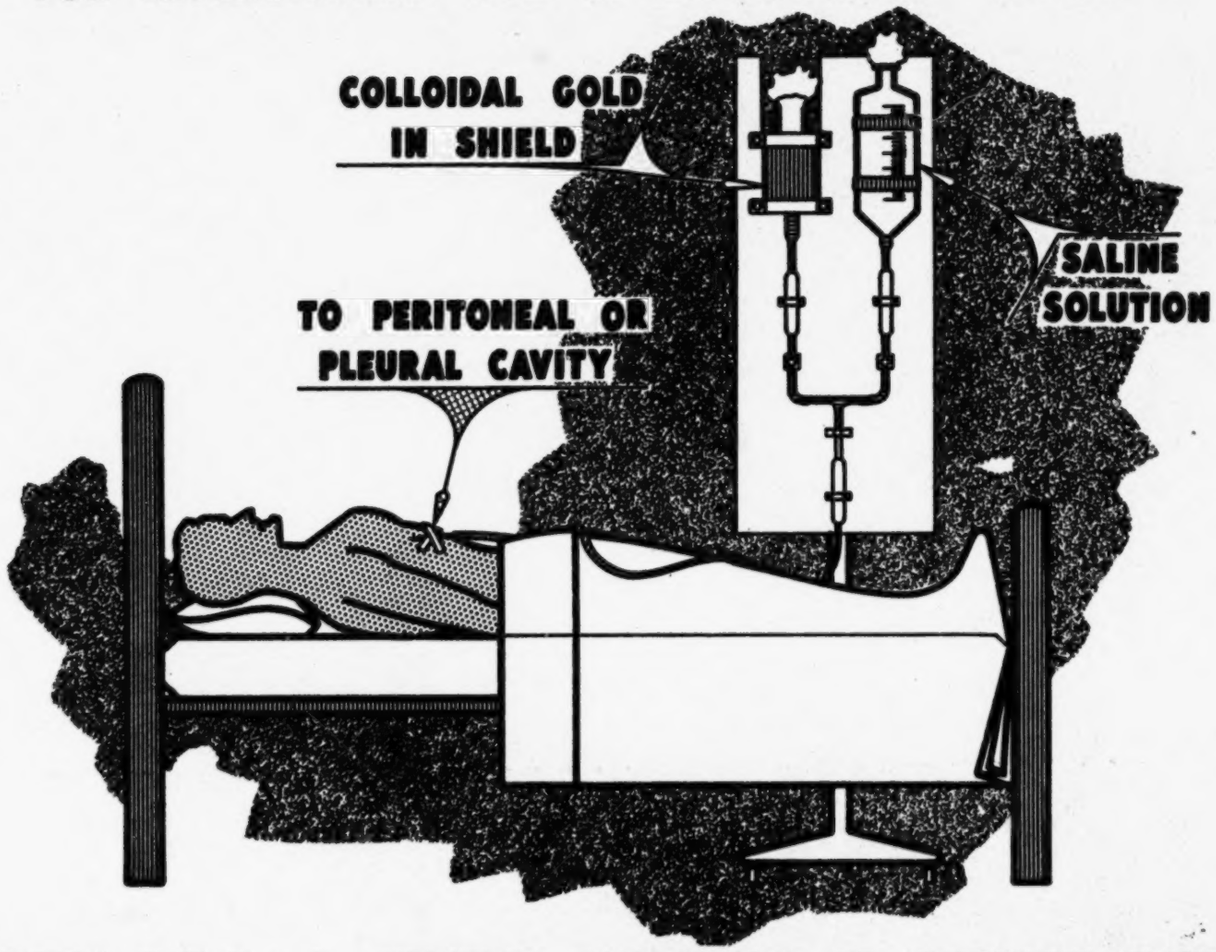
METHOD FOR INTRACAVITARY INFUSION OF RADIOGOLD COLLOID



USAEC-ID 487

RADIOACTIVE GOLD – Au 198

FOR INTRACAVITARY USE IN METASTASIZED CANCER



ADVANTAGES:

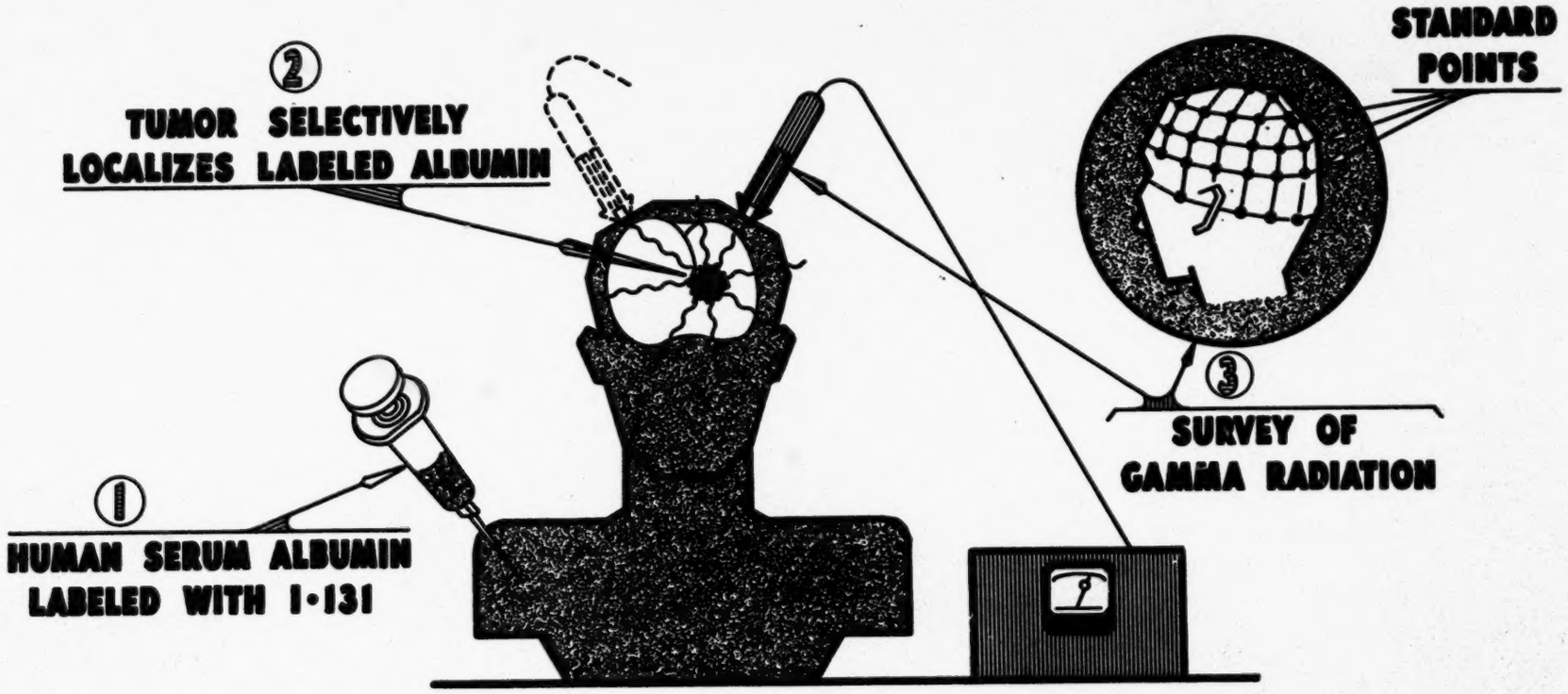
1 - INHIBITS FORMATION OF CAVITARY FLUID

2 - REDUCES PAIN

3 - HELPS RETURN PATIENT TO NORMAL ACTIVITY

USAEC-ID-18A

LOCATING BRAIN TUMORS
WITH
I·131–TAGGED HUMAN SERUM ALBUMIN



AID TO DIAGNOSIS PRIOR TO SURGERY

LOCATES TUMORS NOT FOUND BY OTHER MEANS

CAN USE MULTIPLE COUNTERS FIXED IN STANDARD POSITIONS

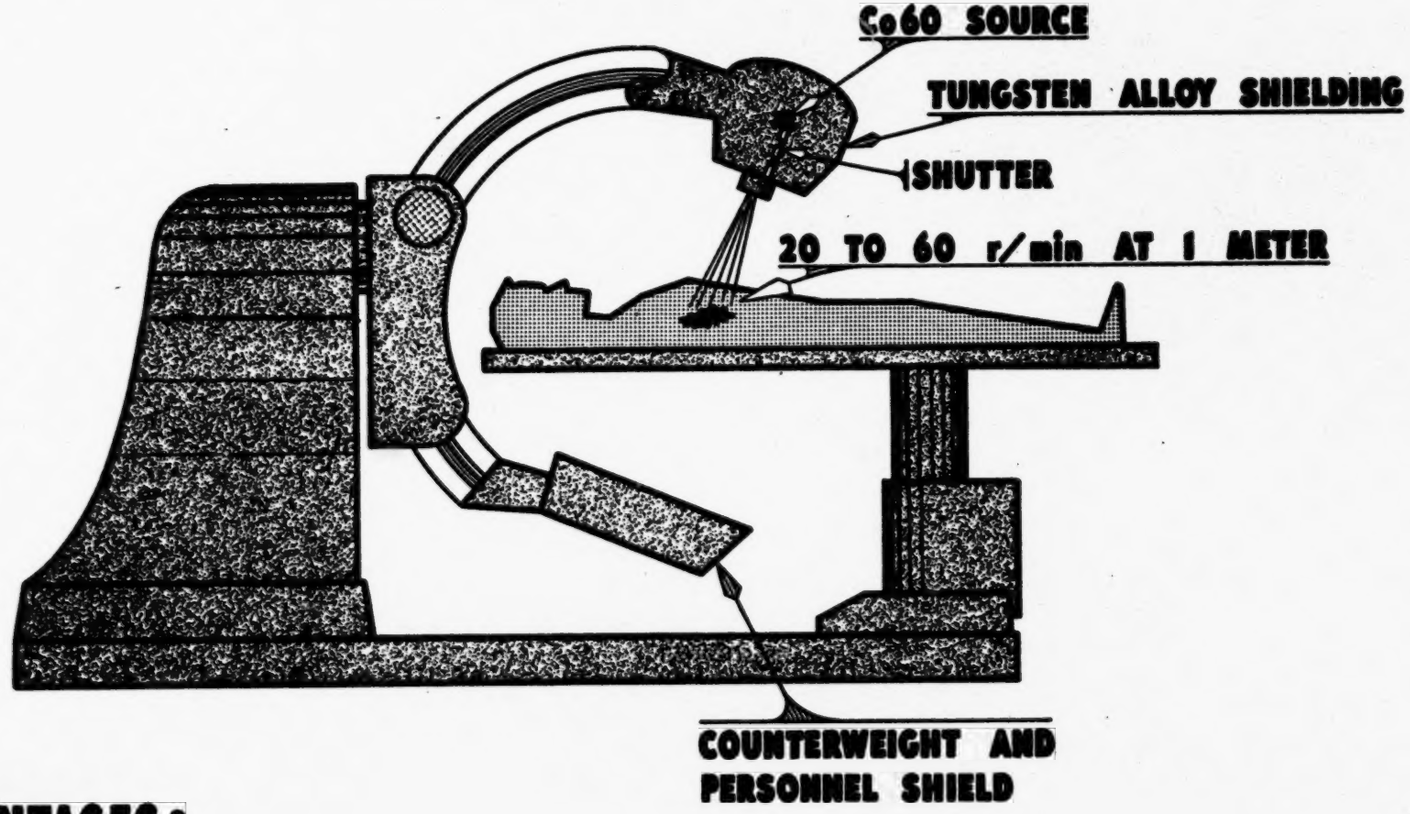
USAEC-ID·154A

ROTATIONAL TELETHERAPY

USING

Co 60 GAMMA RAYS

(FRANCIS DELAFIELD HOSPITAL – NYC)



ADVANTAGES:

1-EFFECTIVE DOSE AT DEEP-SEATED TUMOR—SMALL DOSE AT SURFACE

2-ALLOWS SELECTION OF IRRADIATION PATTERNS

3-ROTATION AND SHUTTER REMOTELY CONTROLLED

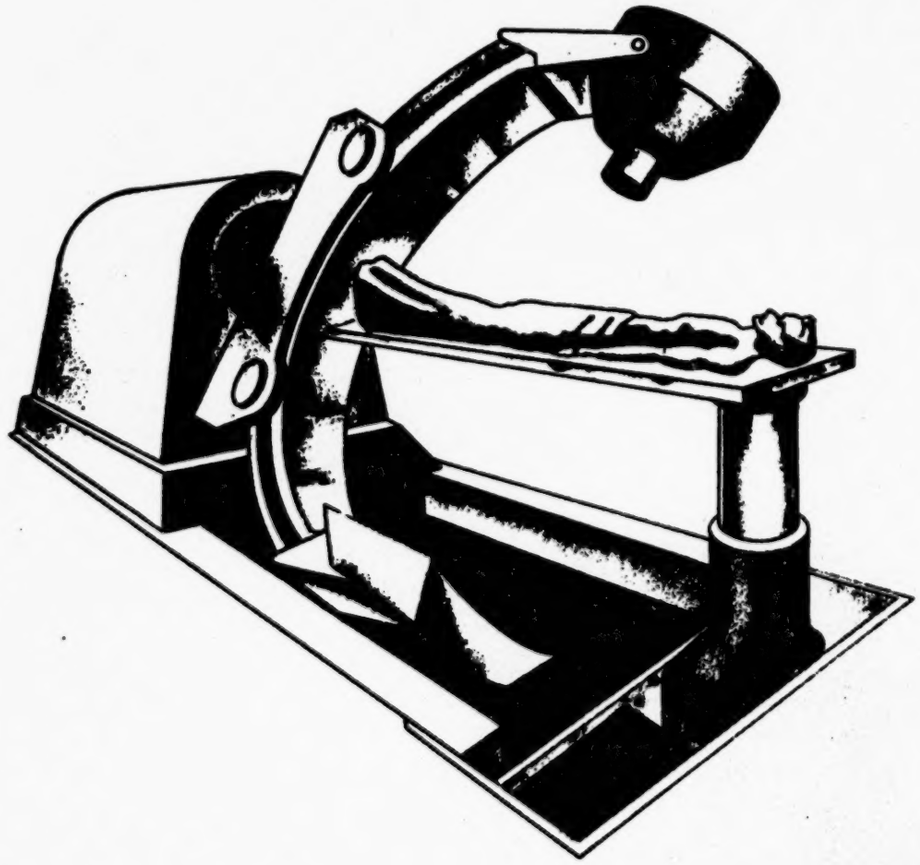
USAEC-ID-1554

ROTATIONAL TELETHERAPY

USING

Co 60 GAMMA RAYS

"THERATRON" — AECL



ADVANTAGES:

1-EFFECTIVE DOSE AT DEEP-SEATED TUMOR — SMALL DOSE AT SURFACE

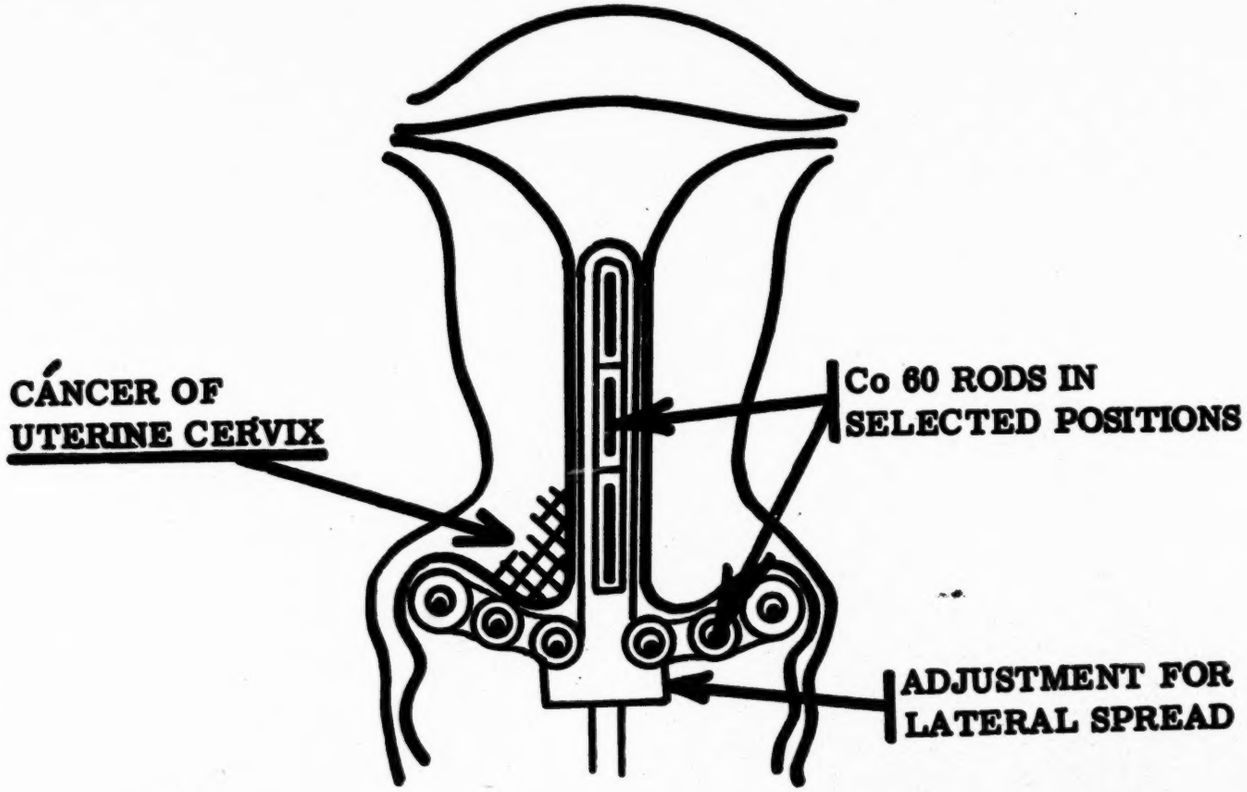
2-ALLOWS SELECTION OF IRRADIATION PATTERNS

3-ROTATION AND SHUTTER REMOTELY CONTROLLED

USAEC-ID-158A

RADIOACTIVE COBALT – Co 60

FOR INTRACAVITARY OR EXTERNAL APPLICATORS



PERMITS WIDE VARIETY OF APPLICATORS

READILY AVAILABLE AND INEXPENSIVE

ALLOWS LARGE INVENTORY OF SPECIAL SOURCES

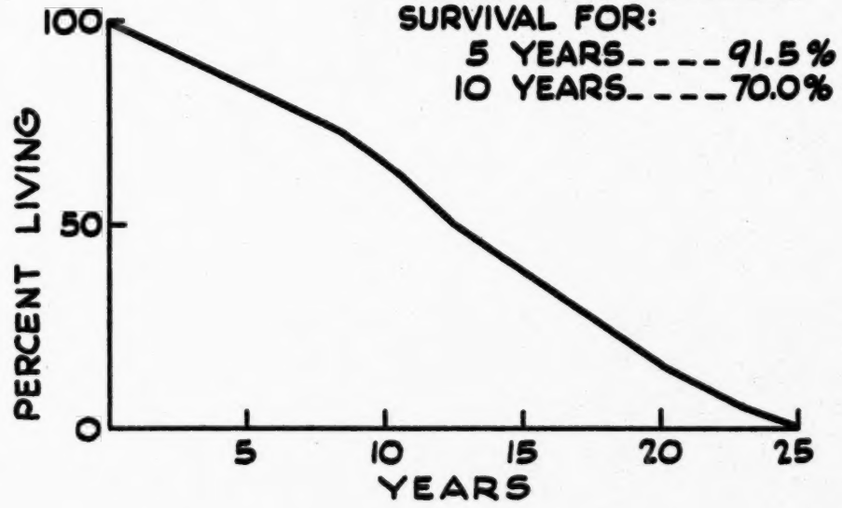
U.S.A.E.C.-ID·235A

Life Expectancy of Polycythemia Vera Patients

AFTER USING

RADIOACTIVE PHOSPHORUS

NO. CASES_____201
AVERAGE AGE_____52
MEDIAN SURVIVAL___13.2
SURVIVAL FOR:
5 YEARS____91.5%
10 YEARS____70.0%



LIFE EXPECTANCY EQUAL TO OR BETTER THAN:

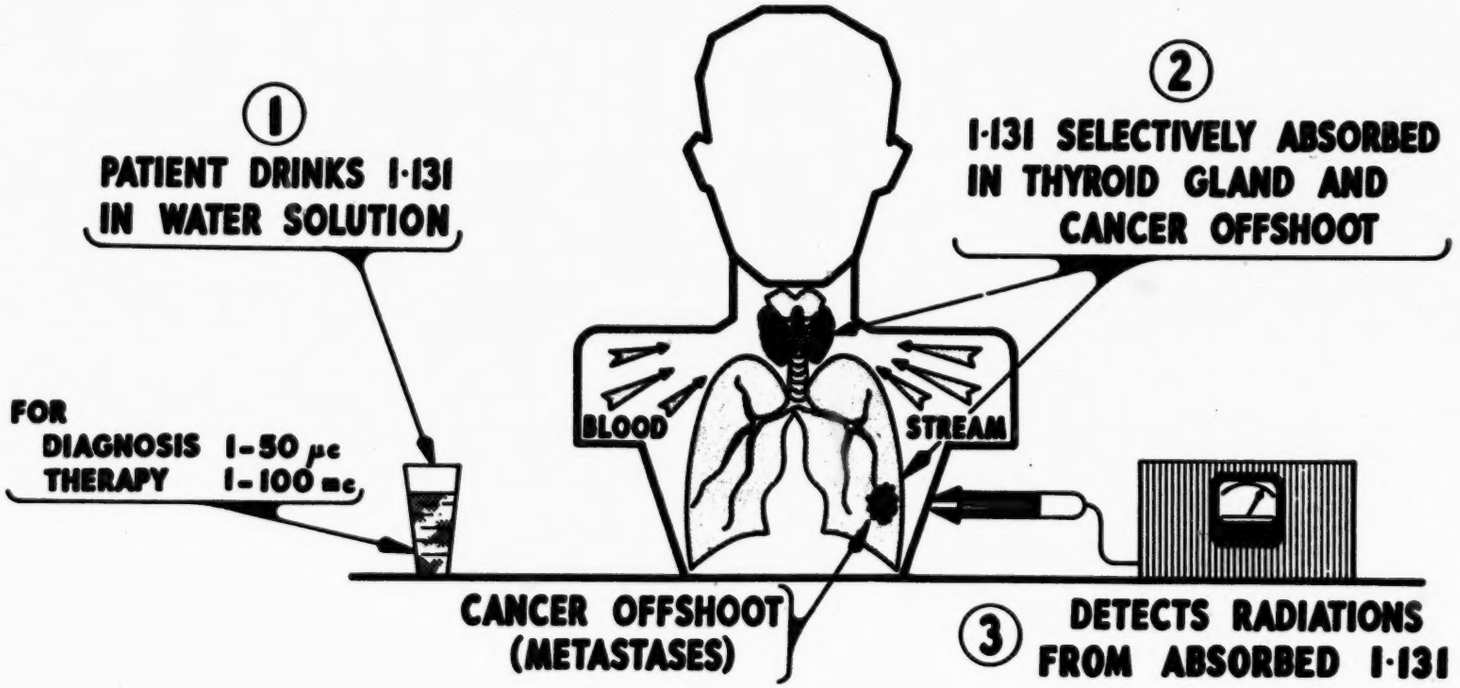
LIVER EXTRACT IN TREATMENT OF PERNICIOUS ANEMIA

INSULIN IN DIABETES TREATMENT

USAEC·ID·279A

RADIOACTIVE IODINE – I·131

FOR DIAGNOSING AND TREATING THYROID GLAND DISORDERS



MEDICAL ACTION:

1 - DIAGNOSIS AND TREATMENT OF HYPERTHYROIDISM

2 - LOCATION OF THYROID CANCER OFFSHOOTS (METASTASES)

3 - TREATMENT OF THYROID CANCER AND METASTASES

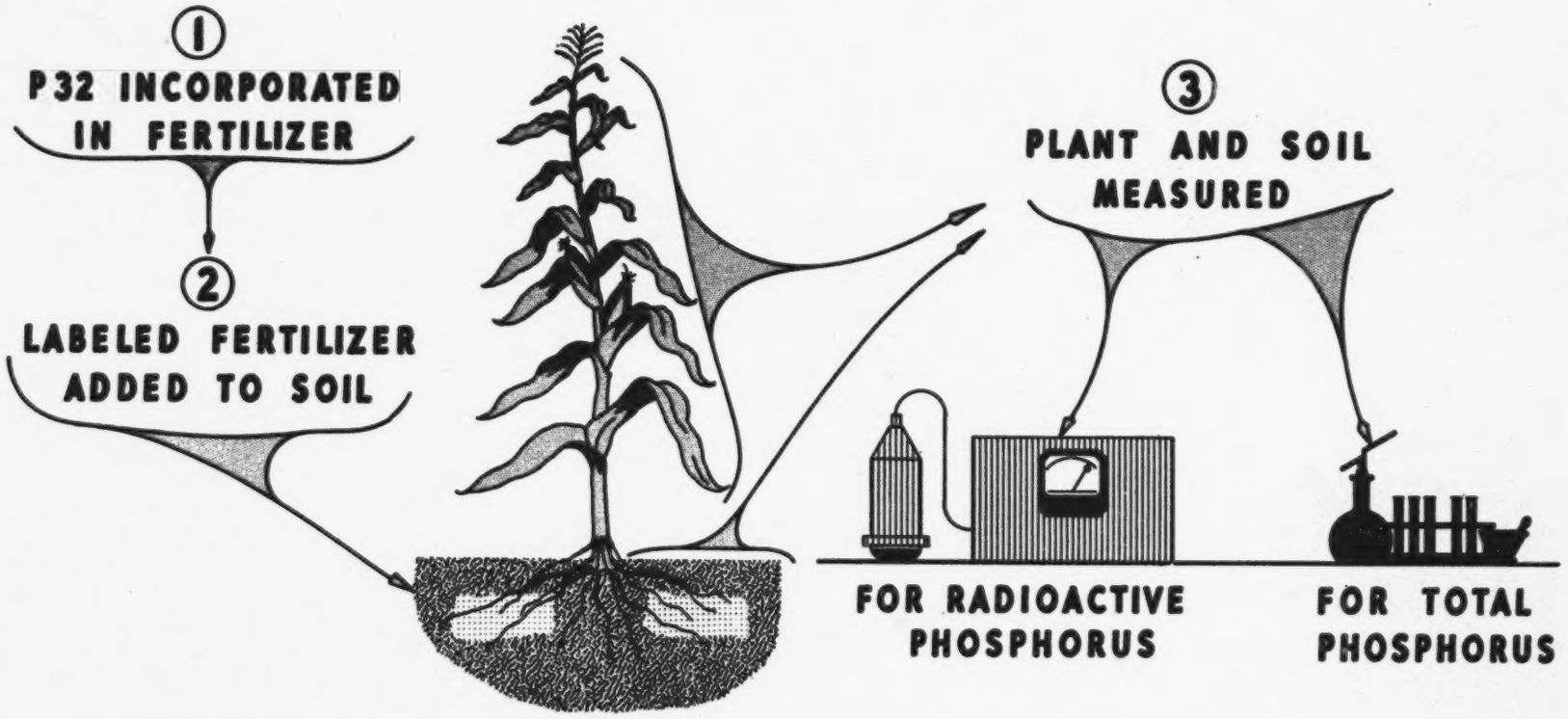
ID-USAEC

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

ILLUSTRATIONS OF ISOTOPE APPLICATIONS IN AGRICULTURE

RADIOACTIVE PHOSPHORUS – P 32

FOR STUDY OF PHOSPHATE FERTILIZER UPTAKE



SHOWS:

1- FIXATION OF PHOSPHORUS BY SOIL

2- PHOSPHORUS UPTAKE BY PLANT

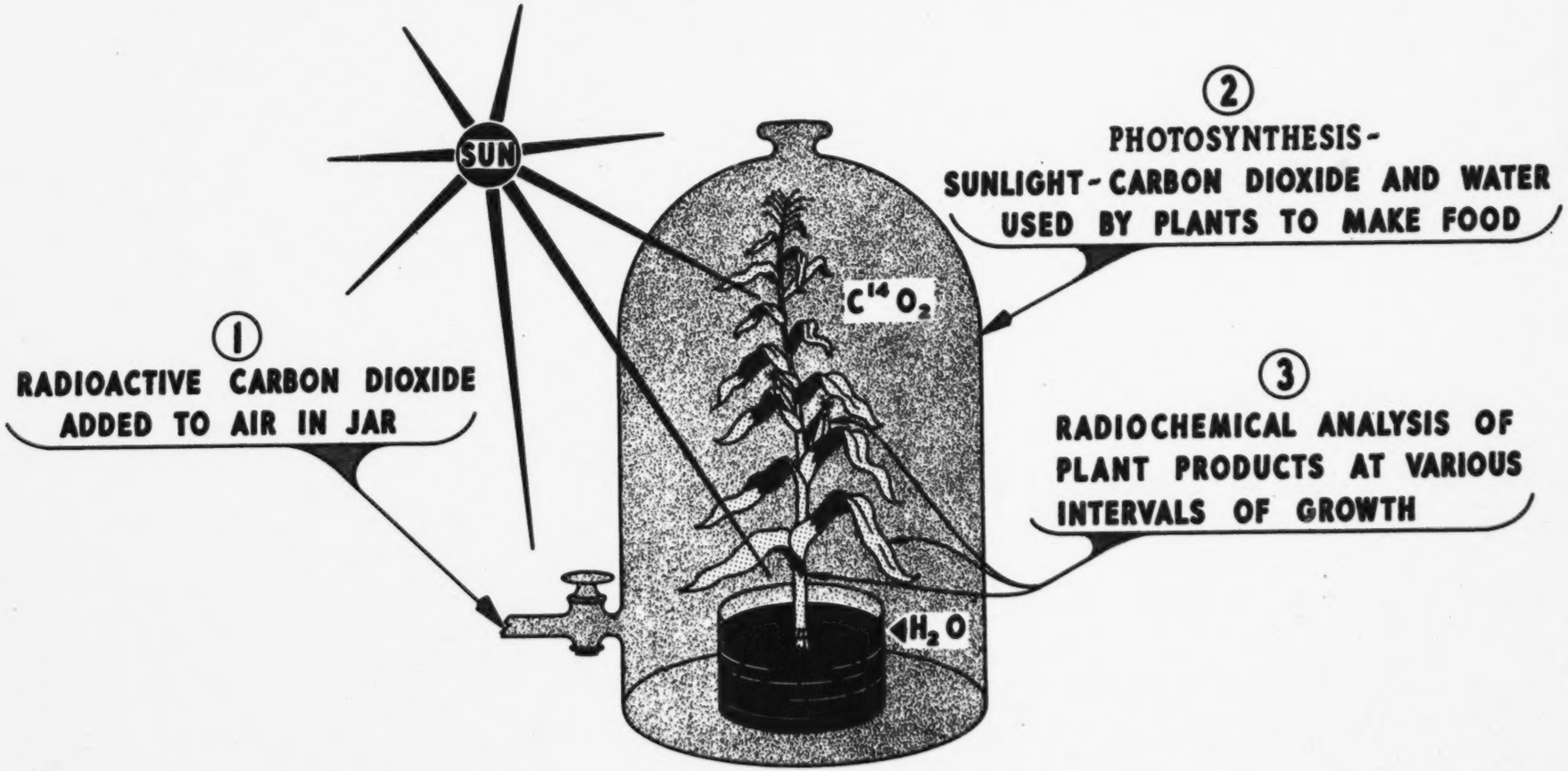
3- PROPER TYPE AND PLACEMENT OF FERTILIZER

4- EFFICIENCY OF FERTILIZER

USAEC-ID-179

RADIOACTIVE CARBON – C14

FOR STUDYING FOOD PRODUCTION BY PLANTS - PHOTOSYNTHESIS



(1) RADIOACTIVE CARBON DIOXIDE ADDED TO AIR IN JAR

(2) PHOTOSYNTHESIS - SUNLIGHT - CARBON DIOXIDE AND WATER USED BY PLANTS TO MAKE FOOD

(3) RADIOCHEMICAL ANALYSIS OF PLANT PRODUCTS AT VARIOUS INTERVALS OF GROWTH

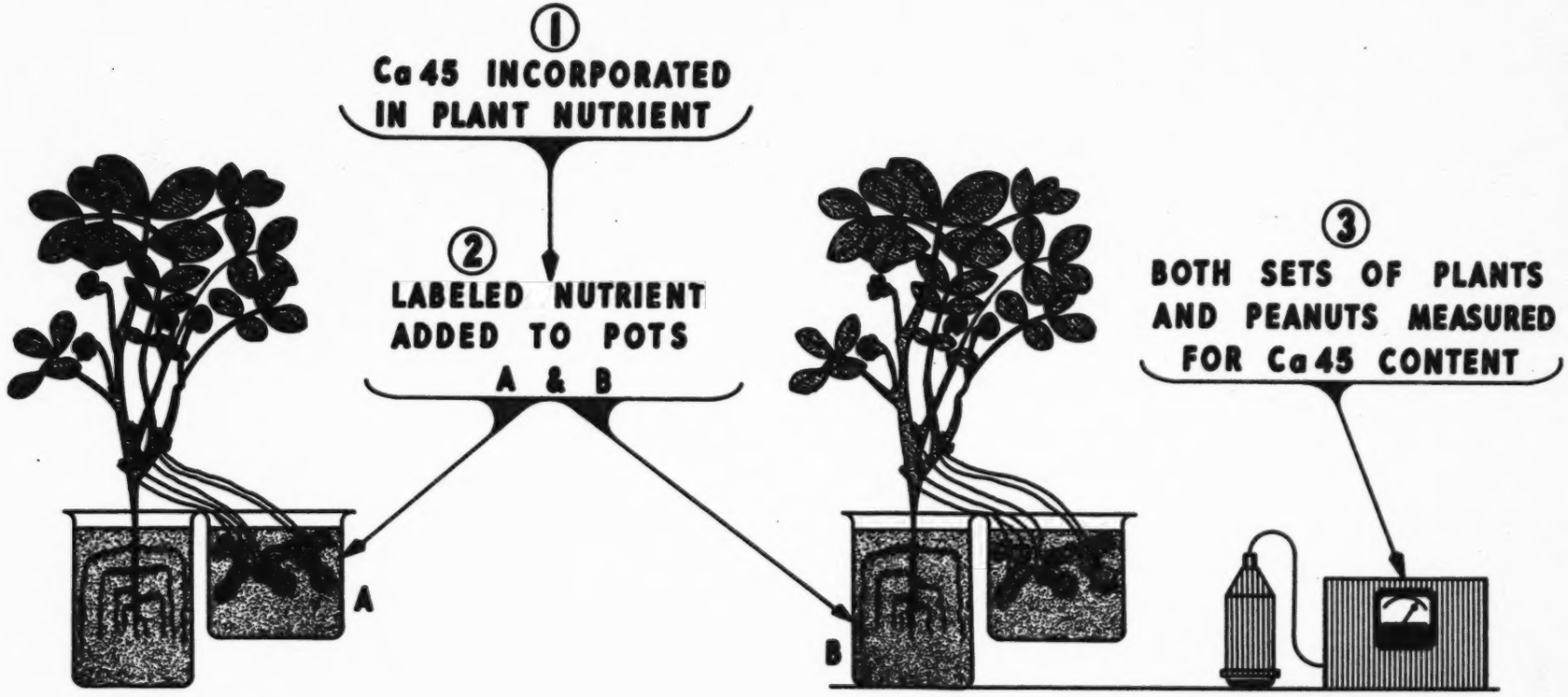
SHOWS:

1 - RAPIDITY OF LIFE PROCESSES
2 - INTERMEDIATE STEPS IN PRODUCING FOODS
3 - ROLE OF CHLOROPHYLL (GREEN PIGMENT)

USAEC-ID-190

RADIOACTIVE CALCIUM – Ca 45

FOR STUDYING PLANT NUTRITION



INDICATES:

1 - ROOTS SUPPLY INSUFFICIENT CALCIUM FOR FRUIT GROWTH

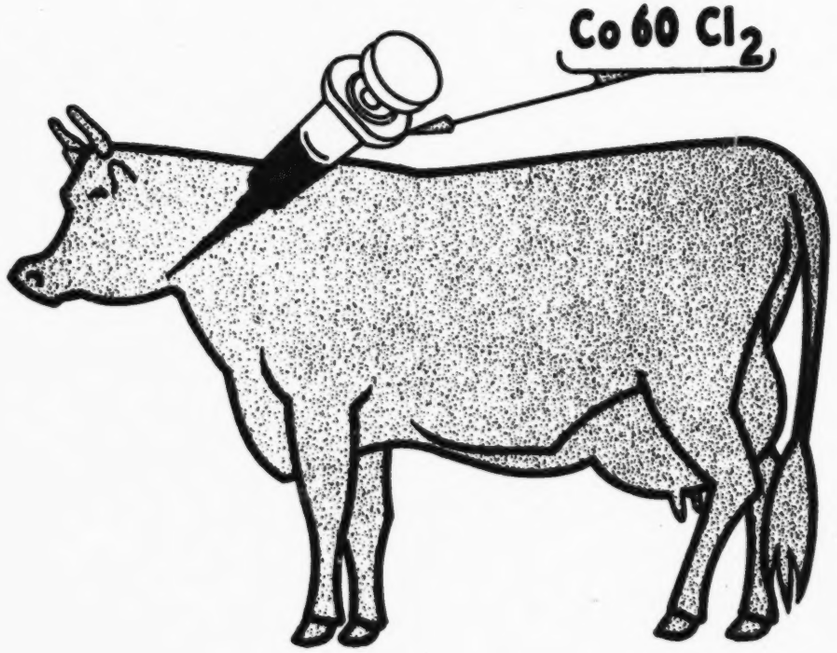
2 - LOCATION OF GREATEST ABSORPTION

3 - ABSORPTION DURING EARLY FRUIT GROWTH

USAEC-ID-192

RADIOACTIVE COBALT – Co^{60}

FOR STUDYING TRACE DEFICIENCIES IN DIET



ADVANTAGES:

1 - RADIO-ANALYSIS RELIABLE FOR TRACE AMOUNTS

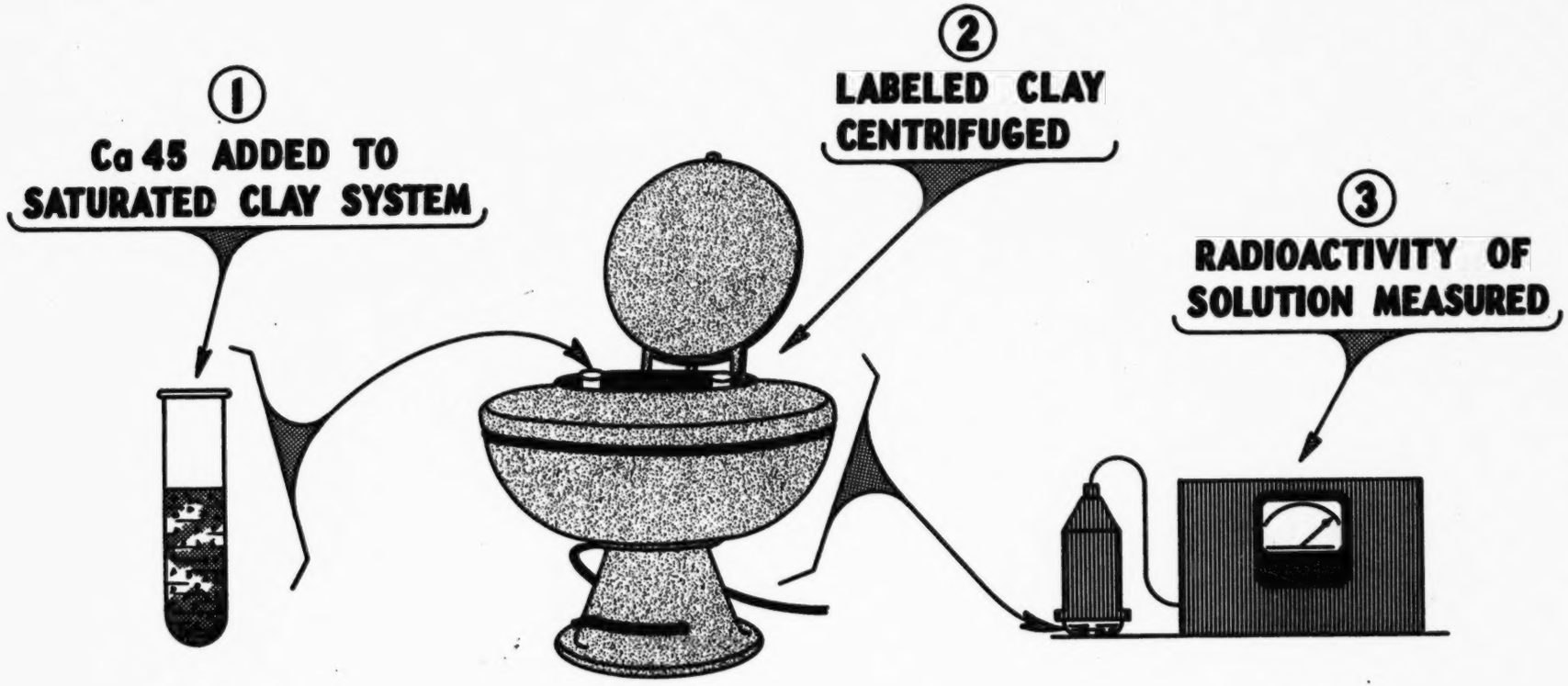
2 - ONLY TRACE AMOUNTS OF Co^{60} NEEDED

3 - METABOLIC ACTION INDICATED

USAEC-ID-276

RADIOACTIVE CALCIUM – Ca 45

FOR STUDYING KINETIC EXCHANGE IN CLAYS



ADVANTAGES:

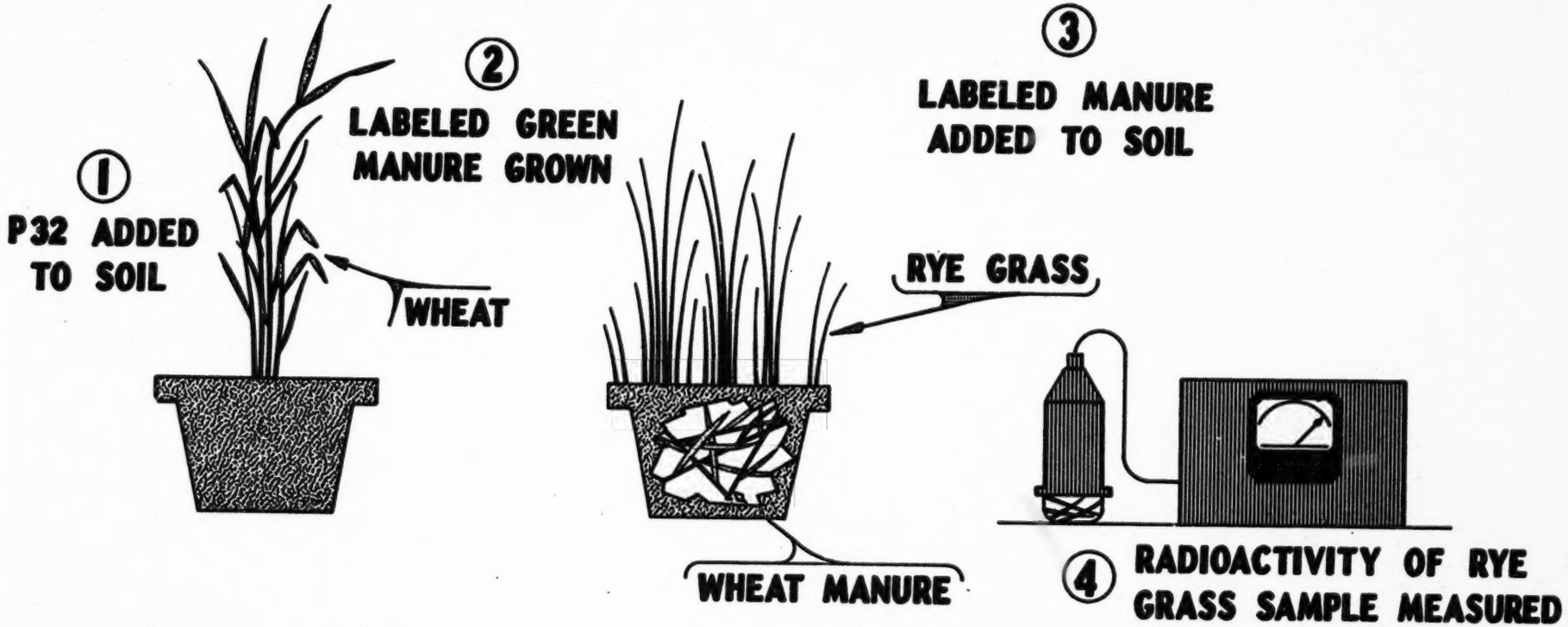
1 - MEASURES EXCHANGE BETWEEN IONS OF SAME ELEMENT

2 - CONFIRMS KINETIC EQUILIBRIUM

USAEC-ID-411

RADIOACTIVE PHOSPHORUS – P32

FOR STUDYING PHOSPHORUS UPTAKE FROM GREEN MANURES



INDICATES:

1 - PHOSPHORUS FROM GREEN MANURE AVAILABLE FOR PLANT USE

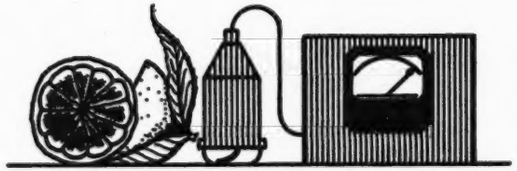
2 - SOIL PHOSPHORUS AND MODE OF PLACEMENT CONTROLS AVAILABILITY

USAEC-ID-412

RADIOACTIVE SULFUR – S35

FOR STUDYING SULFUR DAMAGE TO CITRUS FRUITS

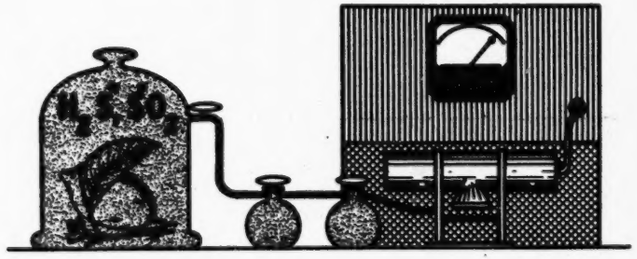
① LABELED SULFUR DUST APPLIED TO FRUIT



② PEEL MEASURED FOR PENETRATION OF S35

③ DETERMINE FORMATION OF INJURIOUS GASES

④ RADIOACTIVITY OF GASES MEASURED



INDICATES:

1 - PENETRATION OF FRUIT PEEL BY SULFUR ATOMS

2 - REACTION WITH FRUIT PEEL TO FORM INJURIOUS GASES

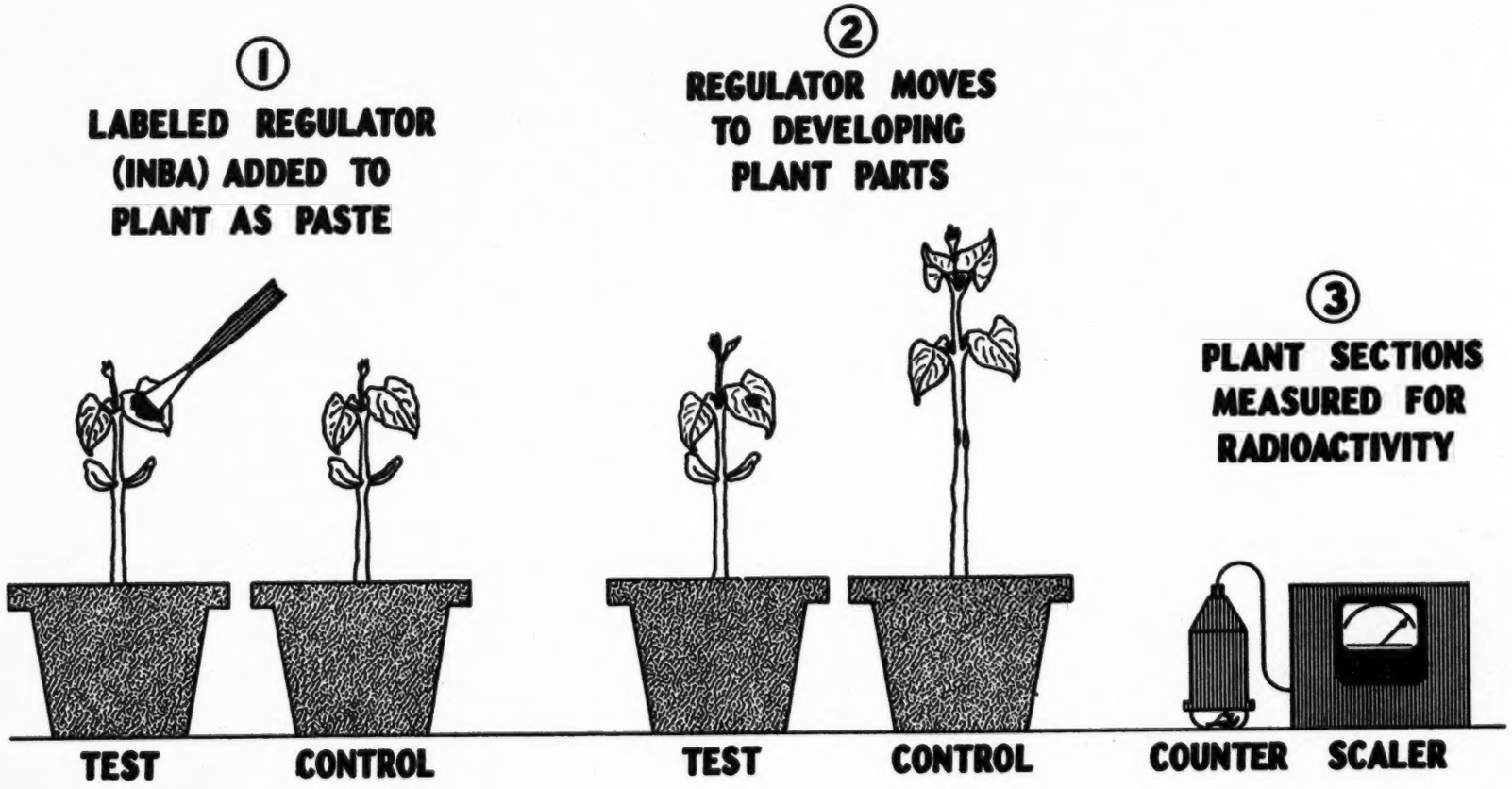
3 - DAMAGE CONFINED TO FRUIT EXPOSED TO SUNLIGHT

4 - DAMAGE INCREASES WITH TEMPERATURE AND HUMIDITY

USAEC-ID-413

RADIOACTIVE IODINE – I-131

FOR STUDYING MOVEMENT OF PLANT GROWTH REGULATORS



INDICATES:

1 - DETAILED PATHWAY OF TRANSLOCATED REGULATOR

2 - REGULATOR TRANSLOCATED TO DEVELOPING PARTS OF PLANT, PROBABLY INTACT

3 - ACCUMULATION OF REGULATOR IN MILLIONTHS OF GRAM RANGE

USAEC-ID-414

RADIOISOTOPES IN AGRICULTURE

PLANT PHYSIOLOGY

- METABOLISM AND TRANSLOCATION
- UPTAKE OF FERTILIZERS
- SOIL FERTILITY
- ACTION OF INSECTICIDES - GROWTH REGULATORS - ETC.
- PATHOLOGY — LEAF BLIGHT - CHLOROSIS - ETC.

ANIMAL HUSBANDRY

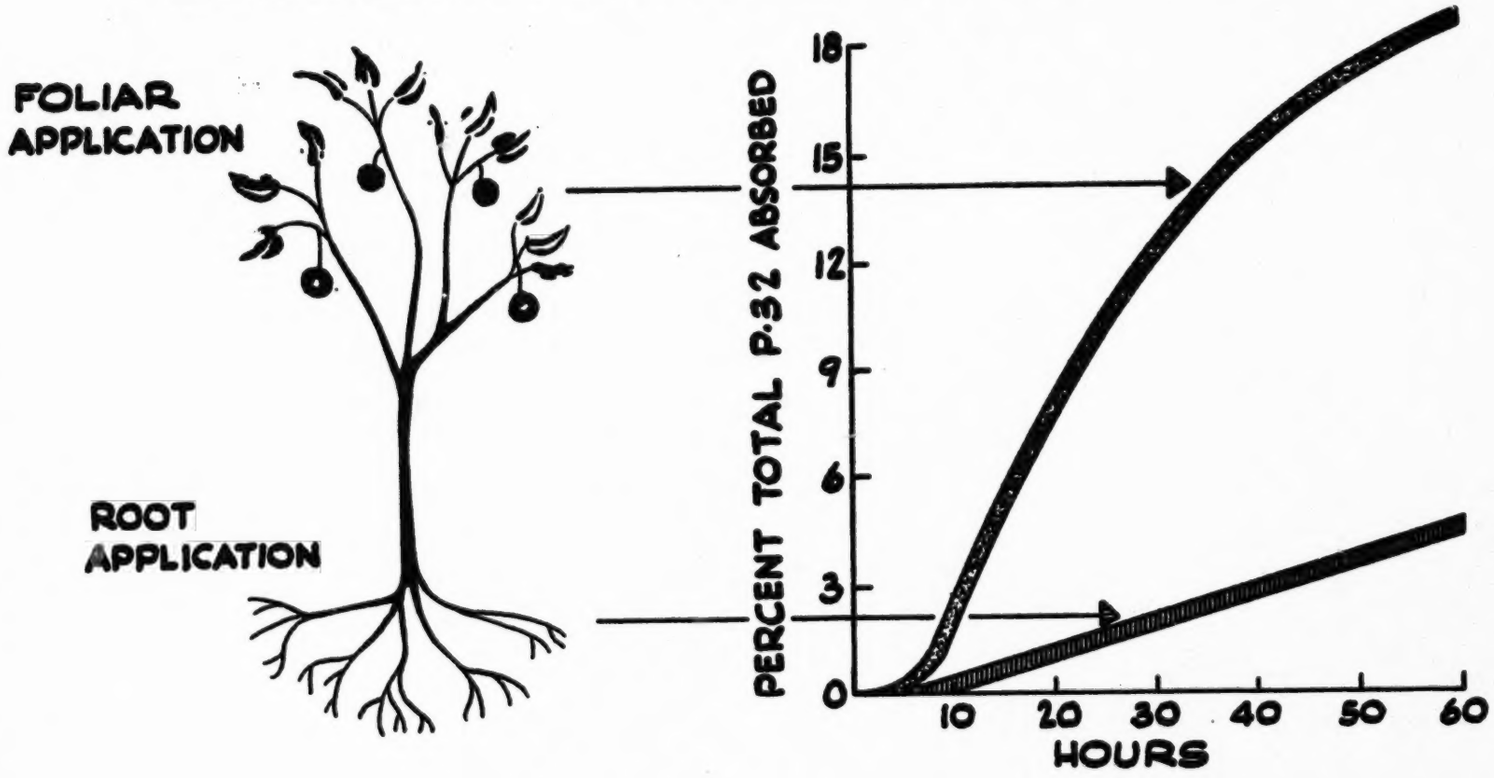
- NUTRITION OF TRACE ELEMENTS
- UTILIZATION OF ORGANIC METABOLITES
- PHYSIOLOGICAL AVAILABILITY OF DIET ADDITIVES
- BIOCHEMISTRY OF MILK PRODUCTION

USAEC-ID-426

Fertilizer Uptake by Roots and Foliage

USING

RADIOACTIVE PHOSPHORUS - P-32



SHOWS: 1-QUICK EFFICIENT WAY TO APPLY FERTILIZER
2-FOLIAR METHOD 95% EFFICIENT — ROOTS 10%
3-CAN BE APPLIED WHEN MOST NEEDED

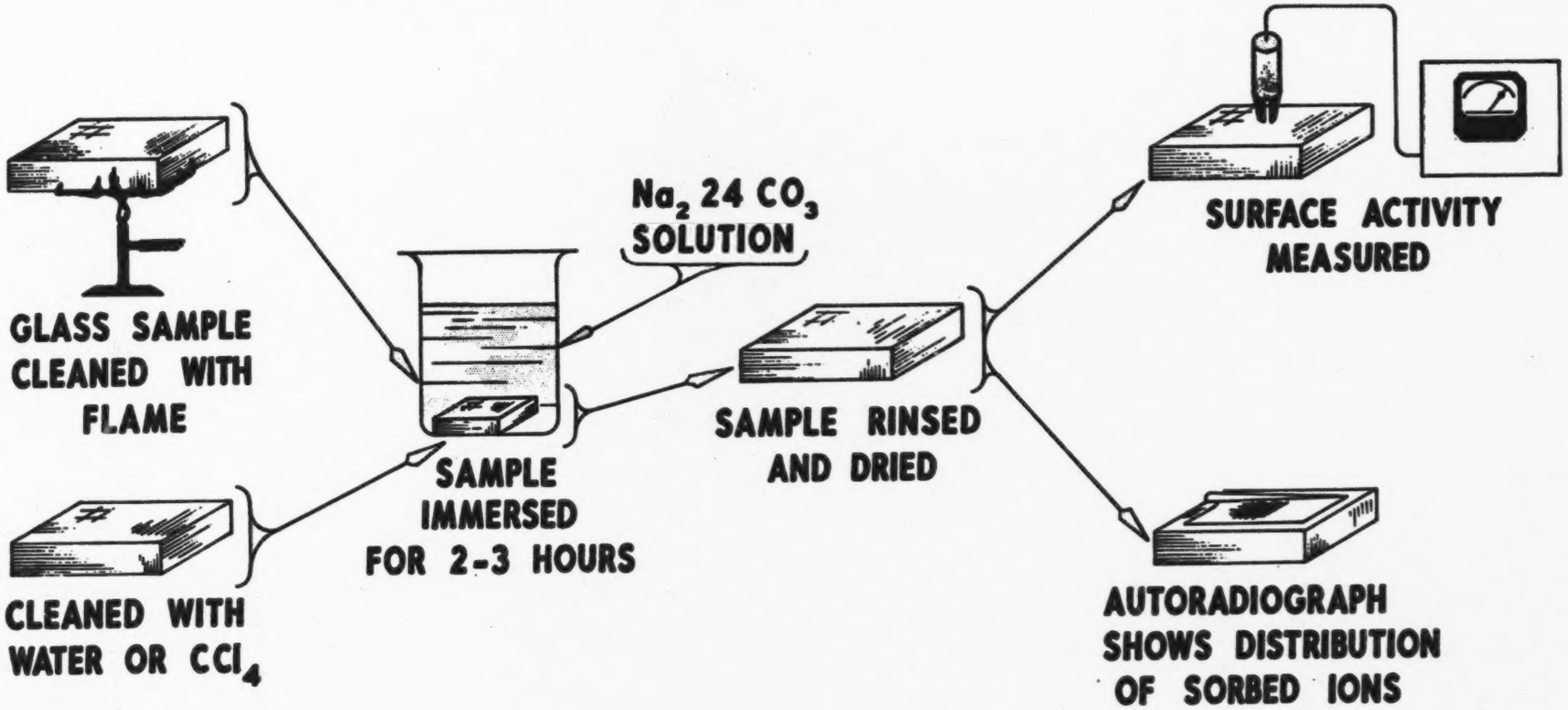
USAEC-ID-277A

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

ILLUSTRATIONS OF ISOTOPE APPLICATIONS IN PHYSICAL SCIENCES

RADIOACTIVE SODIUM – Na 24

FOR STUDYING ION SORPTION ON SOLID SURFACE



SHOWS:

1- SORPTION AT 90°C TEN TIMES GREATER THAN SORPTION AT 25°C

2- INITIAL RATE DECREASED FIVE TIMES BY DECREASE IN pH FROM 12 TO 5

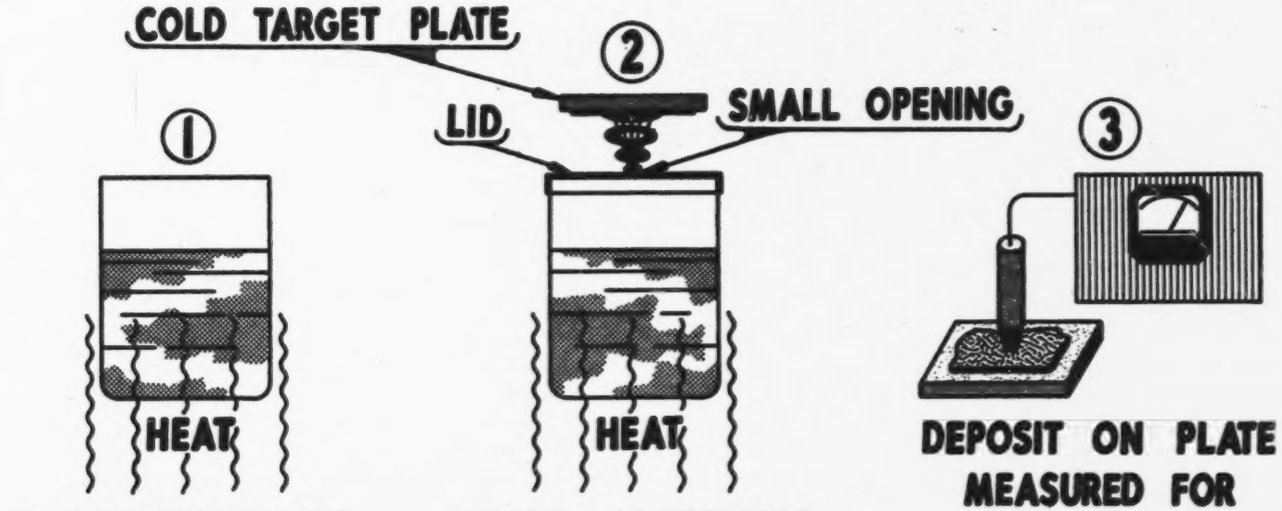
3- SORPTION RATE DEPENDENT ON SURFACE CLEANLINESS

4- FLAME BETTER CLEANER THAN CCl_4 AND WATER

USAEC-ID-219

RADIOACTIVE ISOTOPES

FOR MEASURING VAPOR PRESSURE OF METALS



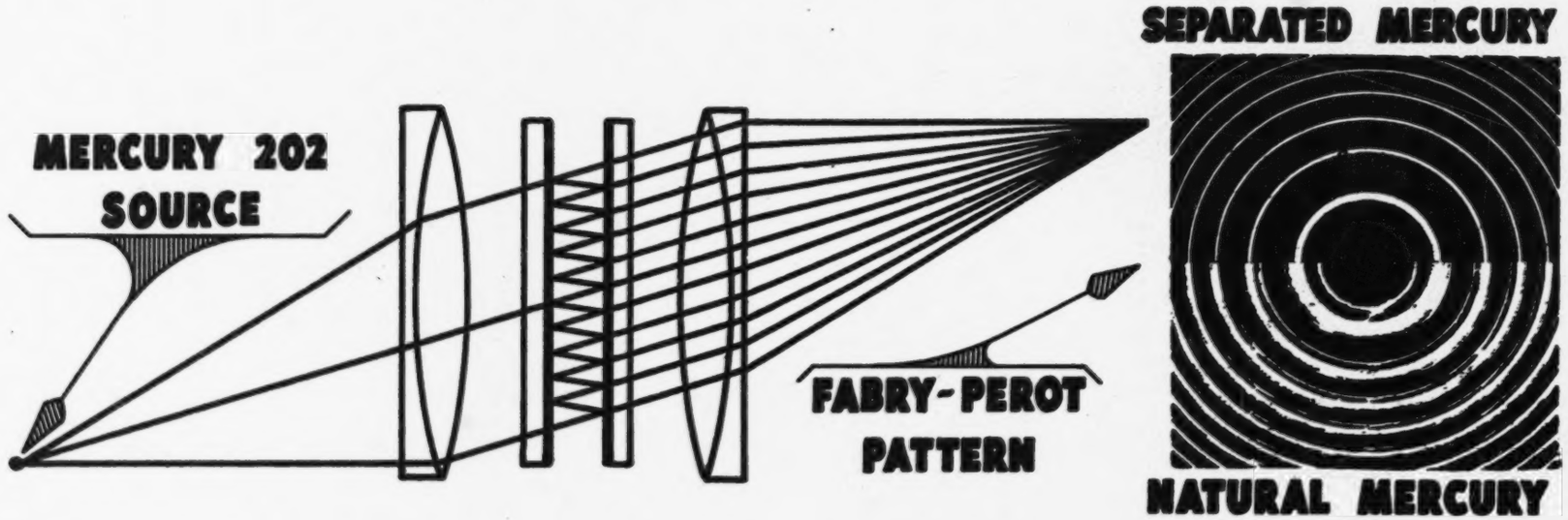
ADVANTAGES:

1 - METHOD MORE ACCURATE THAN CHEMICAL OR PHYSICAL METHODS

2 - EXPERIMENTAL TECHNIQUES NOT DIFFICULT OR TEDIOUS

USAEC-ID-228

SEPARATED MERCURY ISOTOPE - Hg 202
FOR NEW PRIMARY WAVE-LENGTH STANDARD



ADVANTAGES: OVER USE OF CADMIUM RED LINE

1 - LINES FREE OF HYPERFINE AND ISOTOPE STRUCTURES

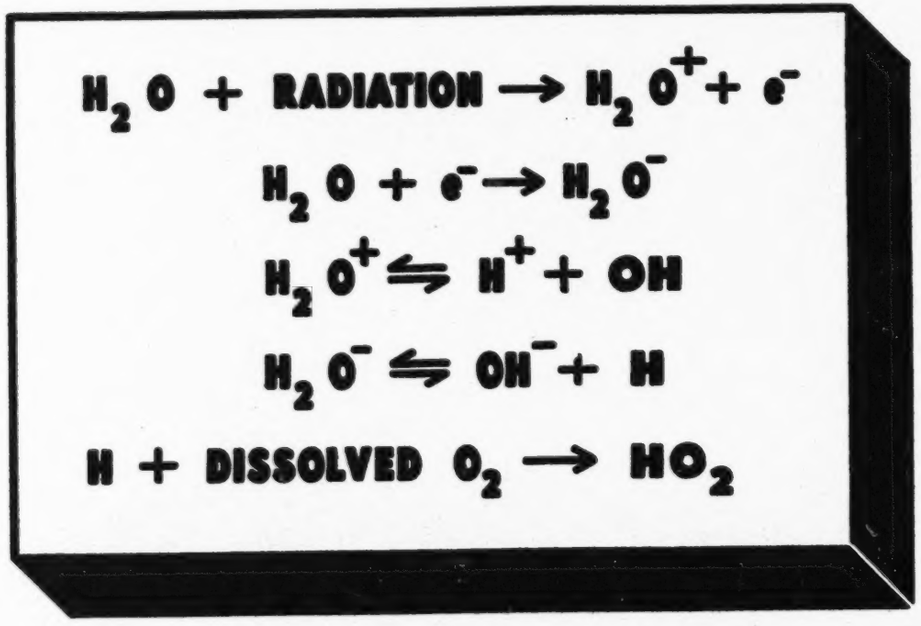
2 - HIGH VISIBLE INTENSITY

3 - MERCURY MORE EASILY EXCITED THAN CADMIUM

4 - PRECISION OF MEASUREMENT (ONE PART PER FIFTY MILLION)

USAEC-ID-17A

DECOMPOSITION OF WATER
BY IONIZING RADIATION



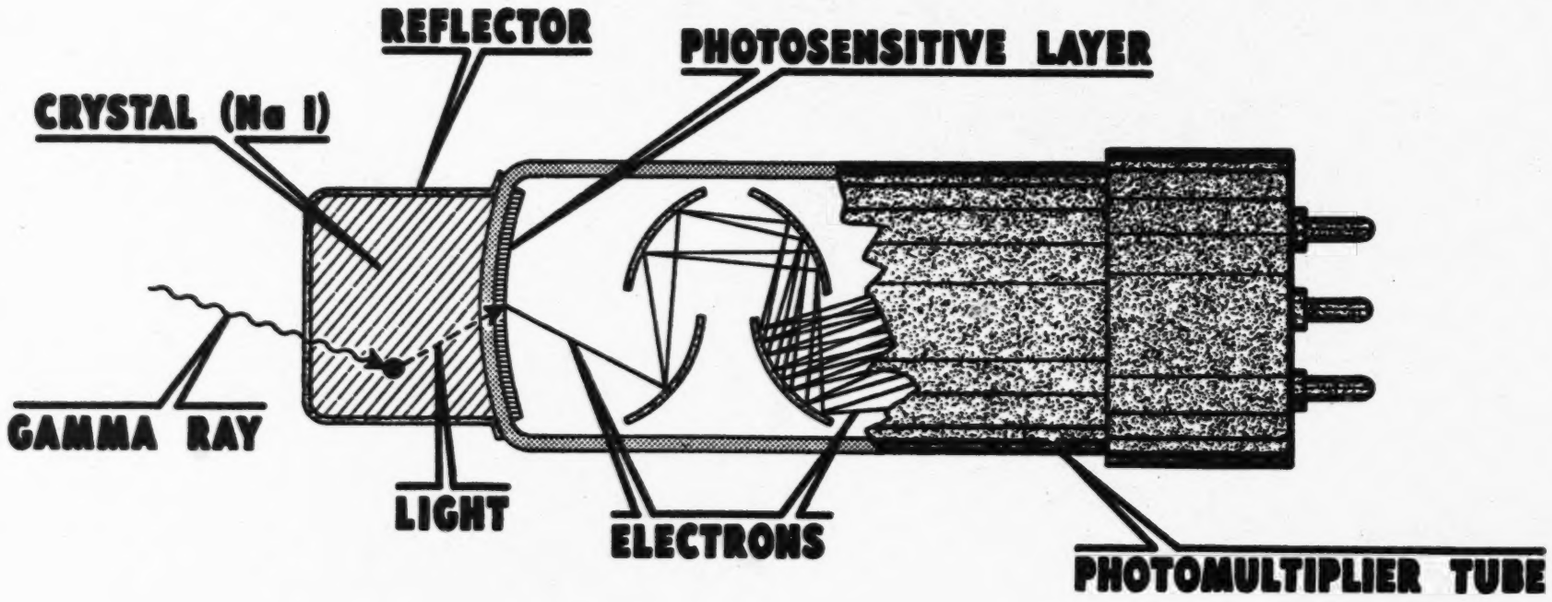
RADICALS H, OH, AND HO_2 BEHAVE AS FREE ATOMS — VERY REACTIVE

OH AND HO_2 OXIDIZE DISSOLVED SUBSTANCES

H REDUCES DISSOLVED SUBSTANCES

USAEC-ID-190A

SCINTILLATION COUNTER



TOTAL LIGHT TO TUBE NEARLY PROPORTIONAL TO GAMMA RAY ENERGY

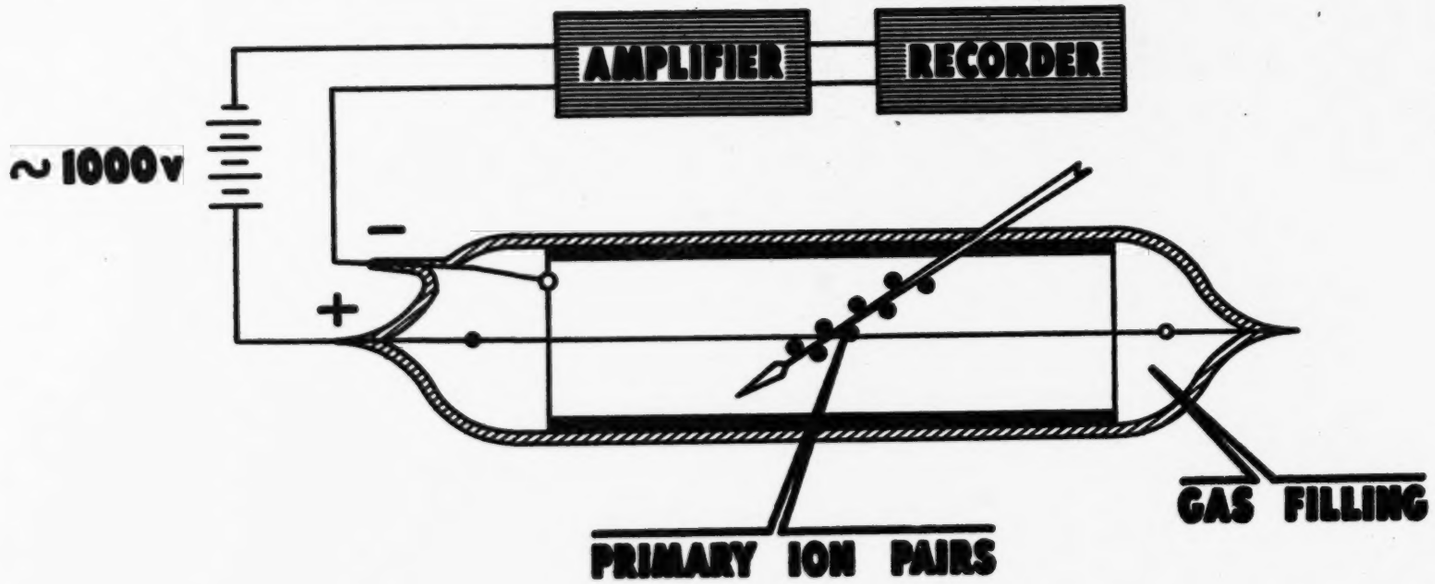
IF 1 ELECTRON EJECTS 5 FROM A DYNODE, 11 DYNODES RESULT IN 5^{11}

OR

ABOUT 50 MILLION ELECTRONS OUTPUT

USAEC-ID-193A

THE GEIGER–MÜLLER COUNTER



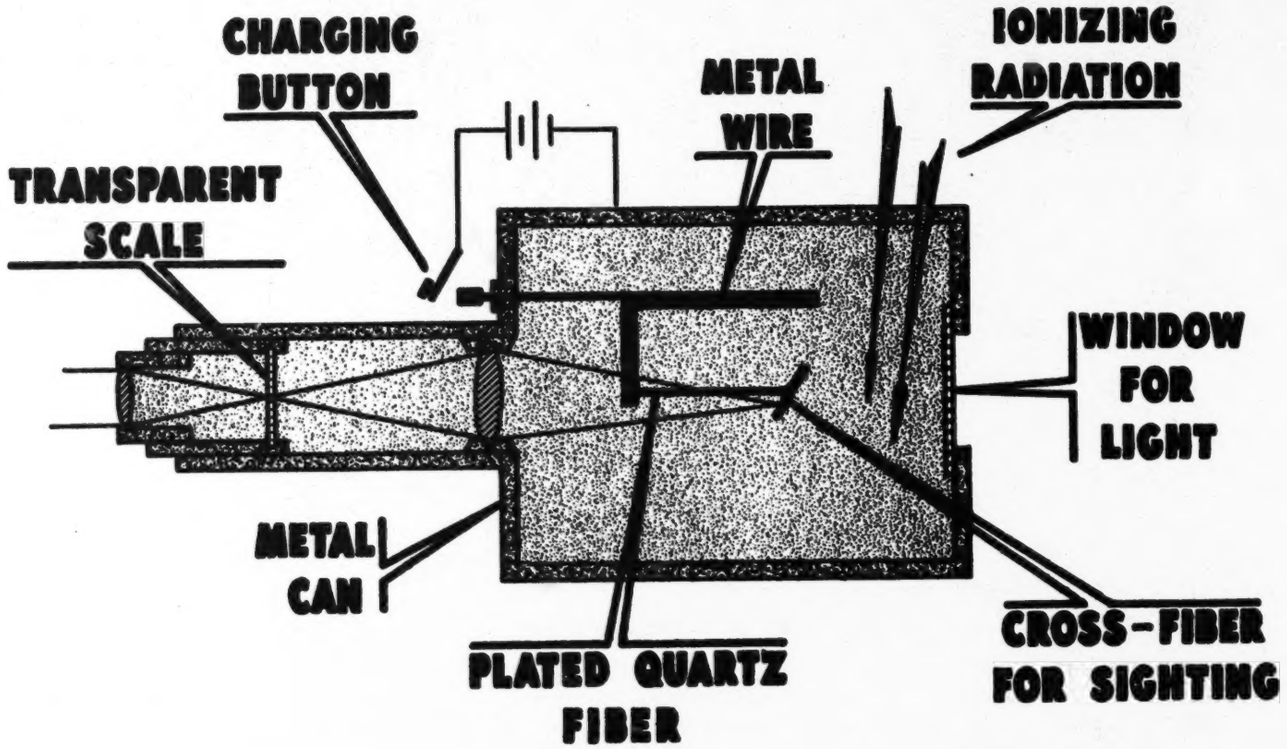
MATERIALS AND FILLING SUITABLE FOR α, β, γ, OR NEUTRONS

THIN CENTRAL WIRE GIVES HIGH FIELD FOR AVALANCHES

1 OR 1,000,000 PRIMARIES GIVE SINGLE PULSE

USAEC-ID-194A

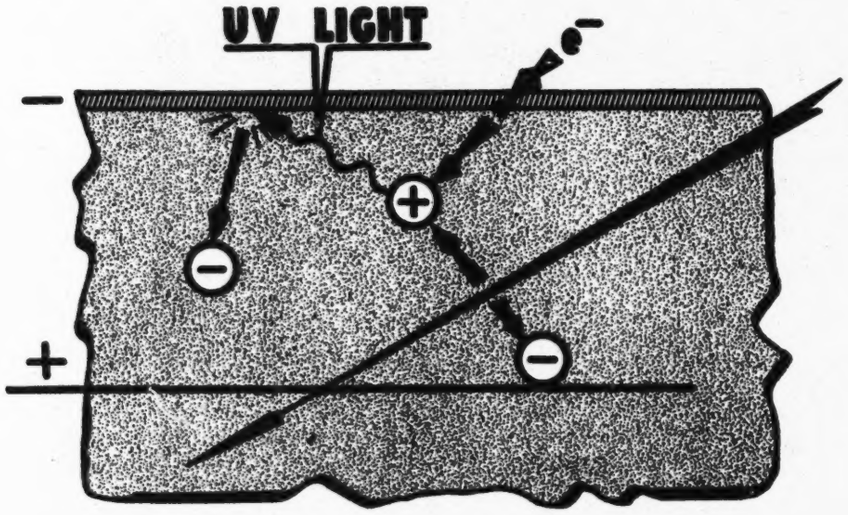
THE LAURITSEN ELECTROSCOPE



- CHARGE BENDS FIBER FROM WIRE
- IONS PRODUCED IN GAS BY RADIATION
- IONS MOVE TO WIRE AND REDUCE CHARGE
- AMOUNT OR RATE OF IONIZATION OBSERVED WITH TELESCOPE

USAEC-ID-195A

NEED FOR QUENCHING
IN G-M TUBE



. POSITIVE ION DRAWS ELECTRON FROM CATHODE

. ION BECOMES EXCITED ATOM

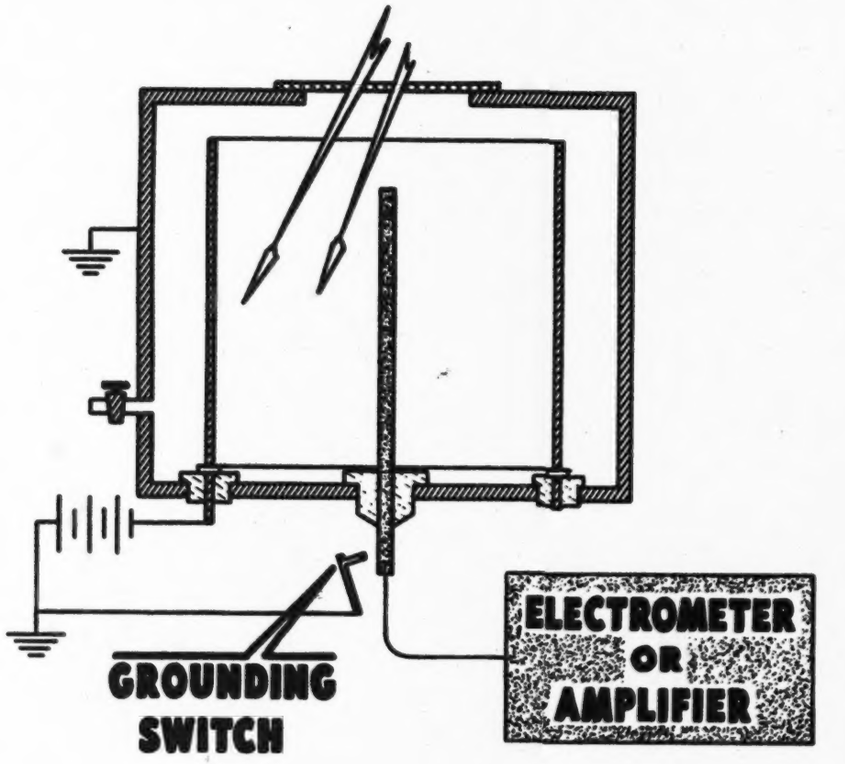
. ATOM RADIATES IN ULTRAVIOLET

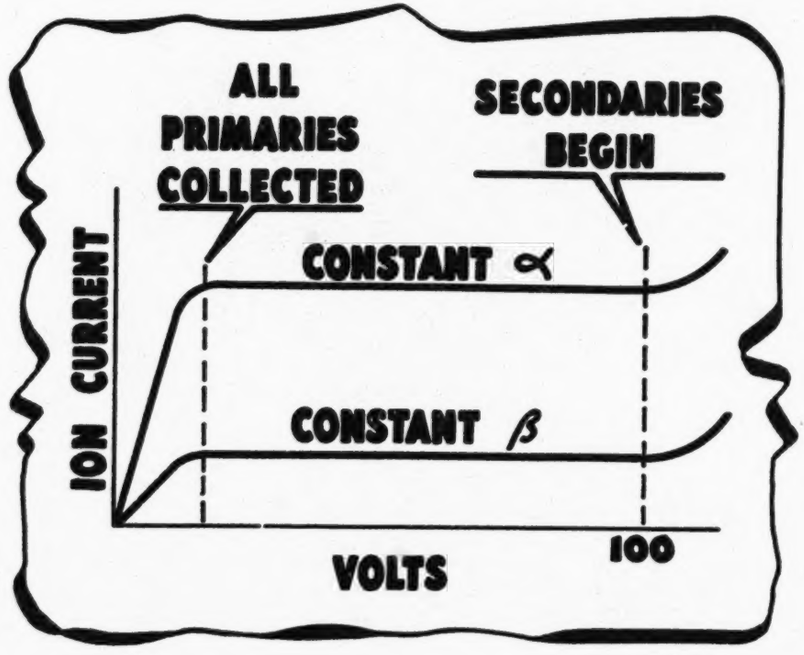
. LIGHT EJECTS PHOTOELECTRON FROM CATHODE

. ELECTRON INITIATES FURTHER CASCADES

USAEC-ID-196A

THE IONIZATION CHAMBER

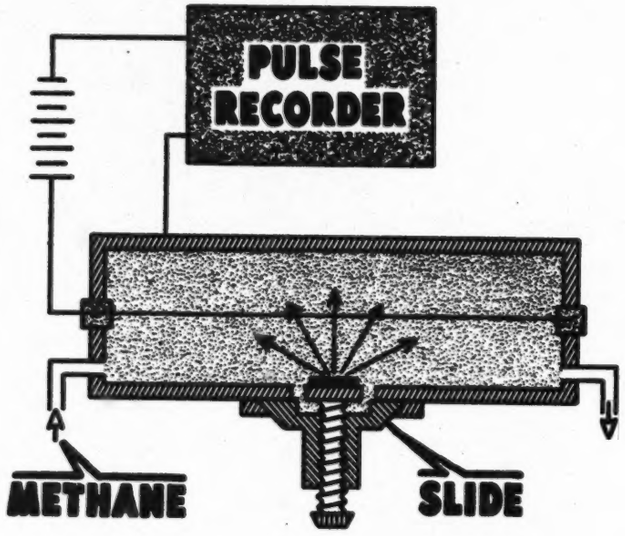




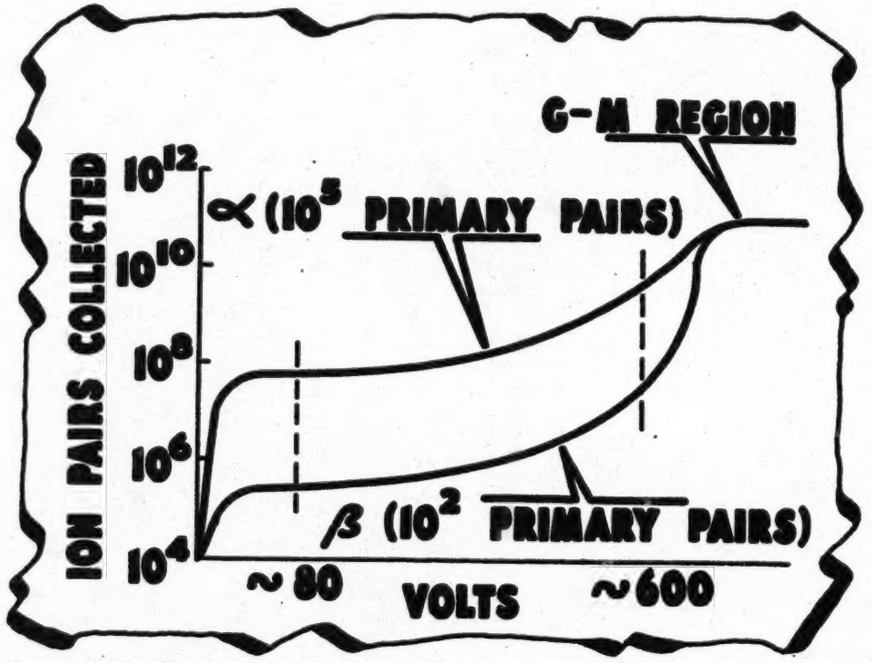
- SENSITIVE TO ALL RADIATIONS
- LOW-ACTIVITY CAN BE MEASURED -- BUT
  - ..AUXILIARIES EXPENSIVE
  - ..ADJUSTMENTS DIFFICULT

USAEC-ID-197A

THE PROPORTIONAL COUNTER



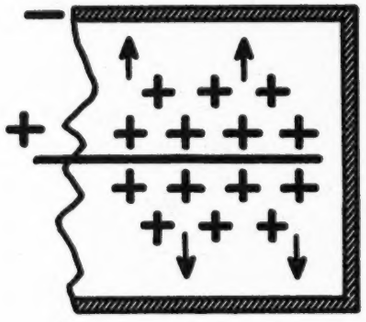
GAS-FLOW TYPE

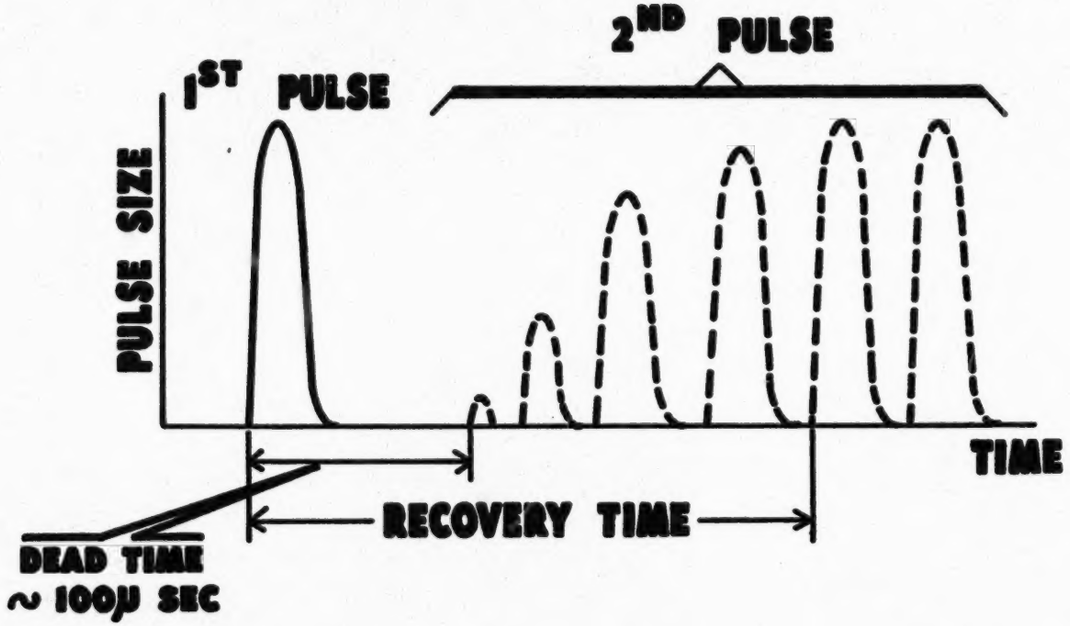


- PULSES PROPORTIONAL TO IONIZING POWER
- RECORDER CAN BE SET FOR PULSE SIZE RANGE
- CAN COUNT α'S IN LARGE FLUX OF β'S
- NO WINDOW TO STOP PARTICLES

USAEC-ID-198A

DEAD TIME OF G-M COUNTER

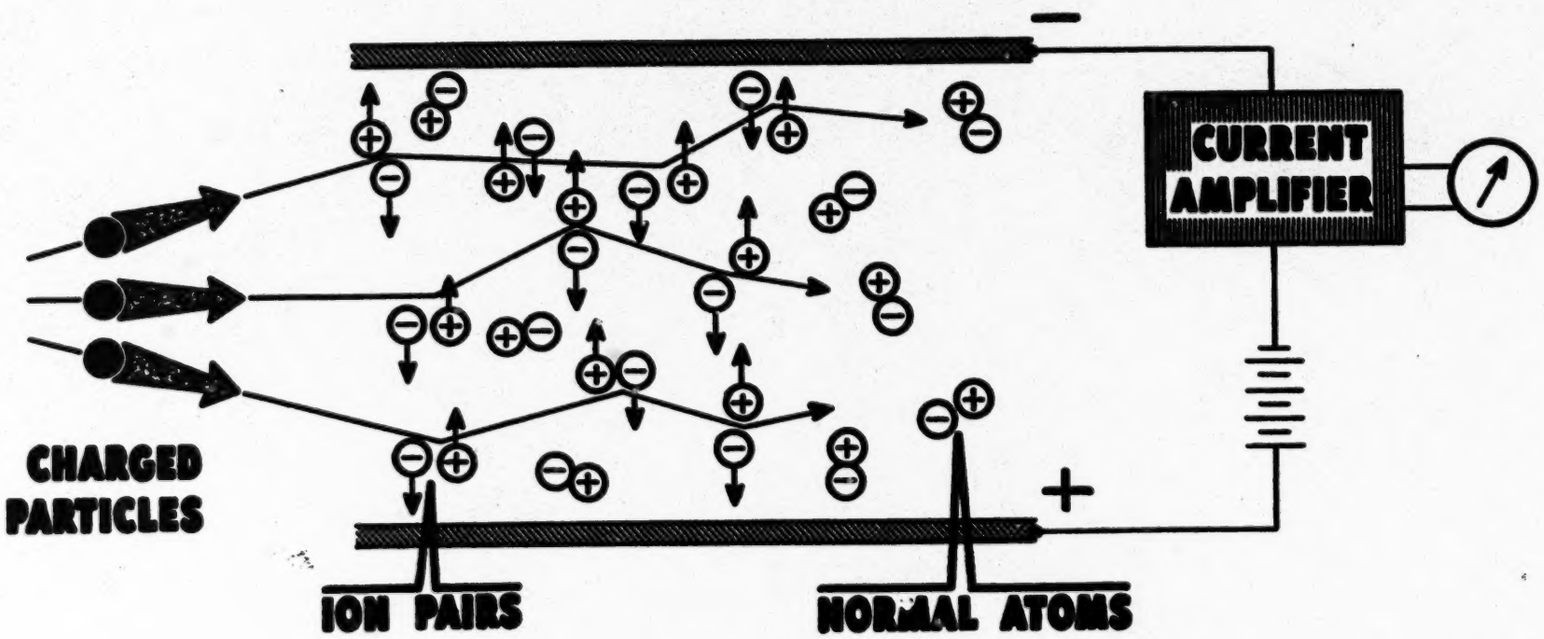




- HEAVY POSITIVE IONS SLOW TO CLEAR
- REDUCE EFFECTIVENESS OF FIELD NEAR WIRE
- REDUCE SPEED OF ELECTRONS
- REDUCE SIZE OF NEXT AVALANCHE

USAEC-ID-199A

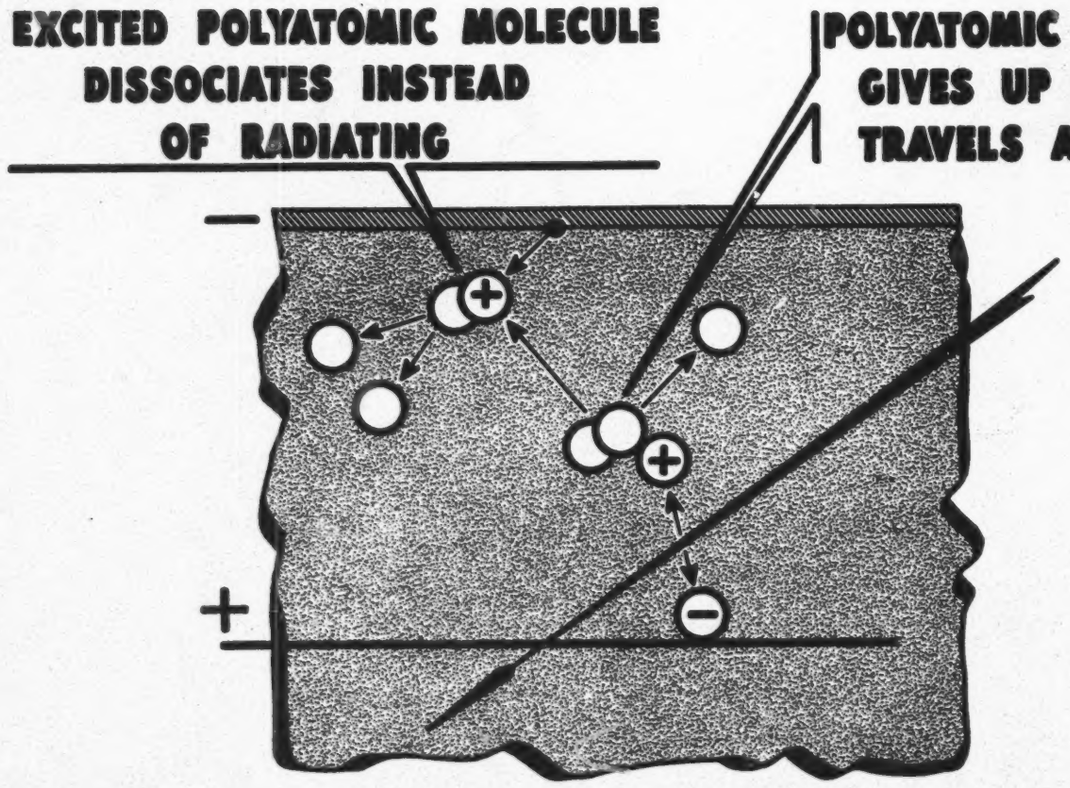
IONIZATION CURRENT



- INCOMING PARTICLES IONIZE ATOMS
- ELECTRODES ATTRACT IONS
- ARRIVAL OF IONS CONSTITUTES CURRENT
- CURRENT IS MEASURE OF PARTICLES

USAEC-ID-200A

ACTION OF QUENCHING GAS
IN G-M TUBES



TYPICAL GAS

90% ARGON

10% ETHYL ALCOHOL OR
AMYL ACETATE, ETC.

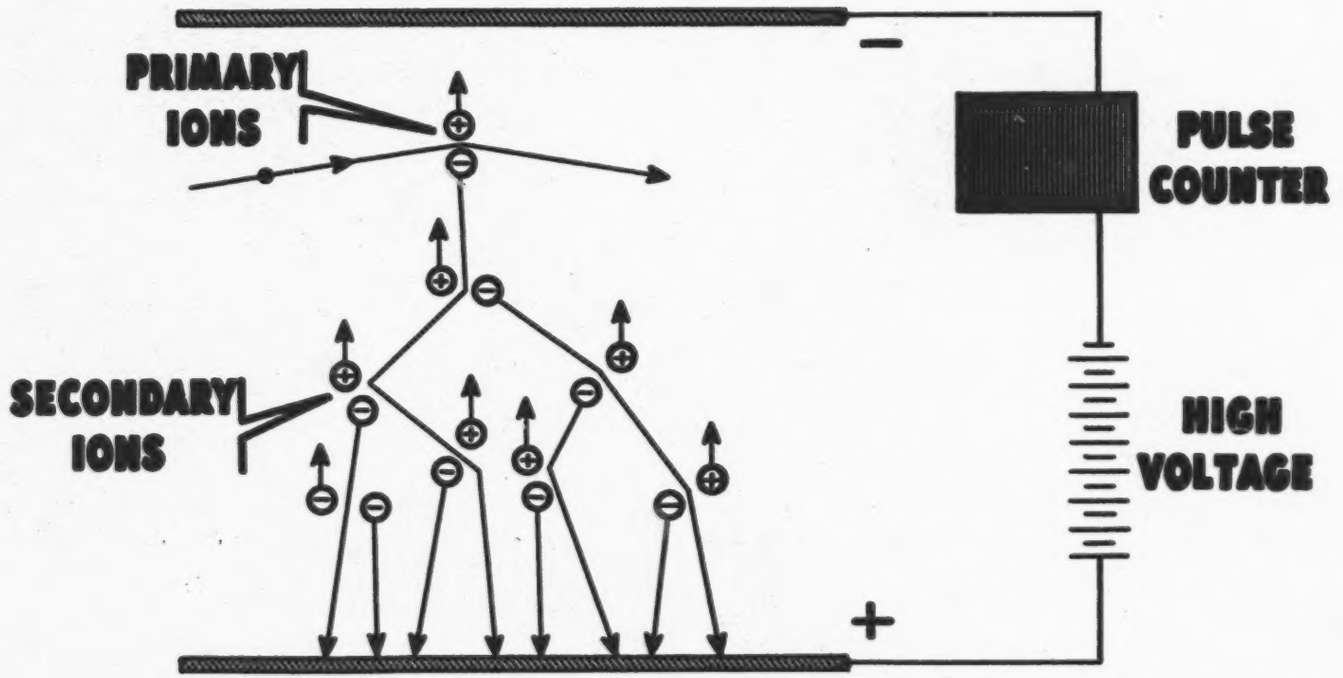
NEARLY COMPLETE SUPPRESSION OF SPURIOUS COUNTS

BUT...

DISSOCIATION OF GAS LIMITS USEFUL LIFE

USAEC-ID-201A

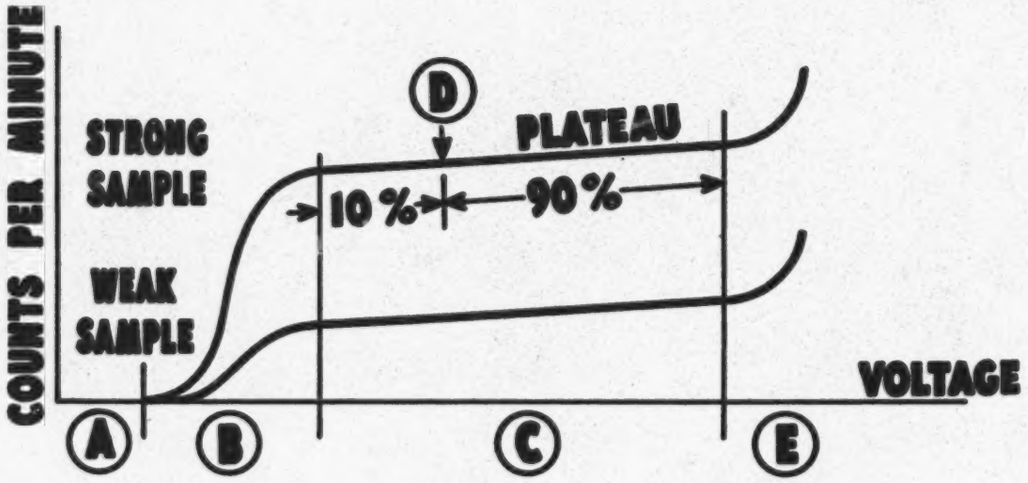
GAS AMPLIFICATION



- ELECTRONS RECEIVE ENOUGH ENERGY TO IONIZE
- AVALANCHE OF SECONDARIES
- CURRENT MULTIPLIED BY 1.000 TO 1.000.000

USAEC-ID-202A

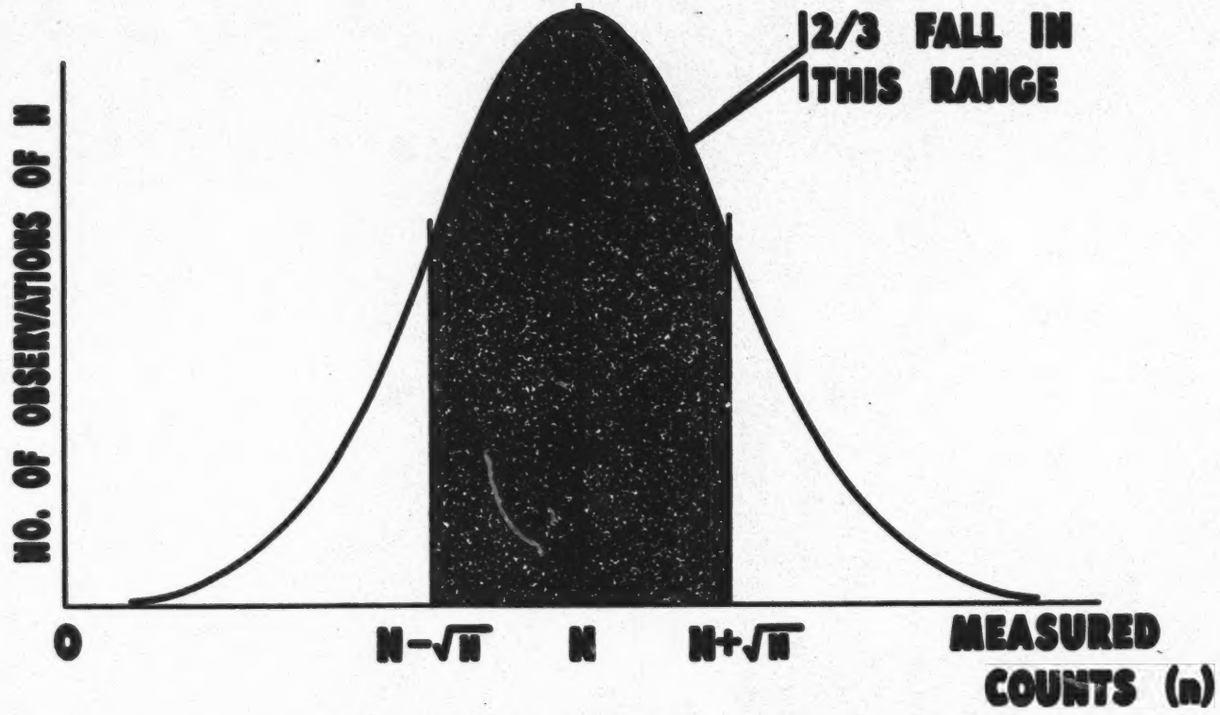
THE GEIGER–MÜLLER PLATEAU



- (A) NO PULSES LARGE ENOUGH FOR RECORDER
- (B) AVALANCHES GROW LARGER WITH VOLTAGE
  NUMBER OF RECORDER PULSES INCREASES
- (C) ALL PARTICLES TRIGGER MAXIMUM AVALANCHE
  ALL PULSES RECORDED
- (D) OPTIMUM SETTING FOR OPERATING VOLTAGE
  HIGHER VOLTAGE GIVES SHORTER TUBE LIFE
- (E) SPURIOUS DISCHARGES LEAD TO BREAKDOWN

USAEC-ID-203A

THE STANDARD ERROR
IN PARTICLE COUNTING

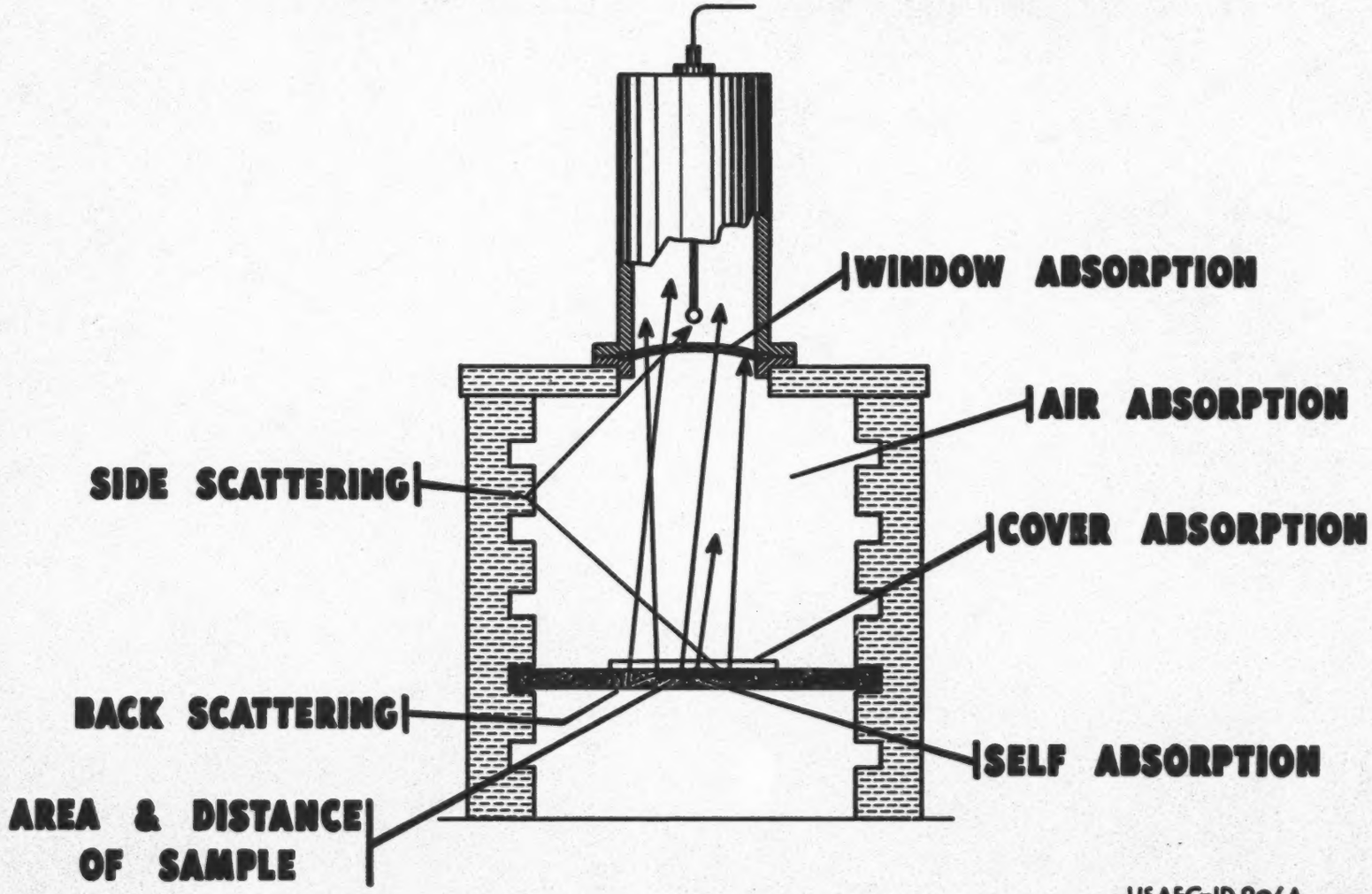


THE PROBABILITY CURVE

... IF UNKNOWN N IS MEASURED AS n,
2/3 OF REPEATS EXPECTED TO BE WITHIN $n \pm \sqrt{n}$

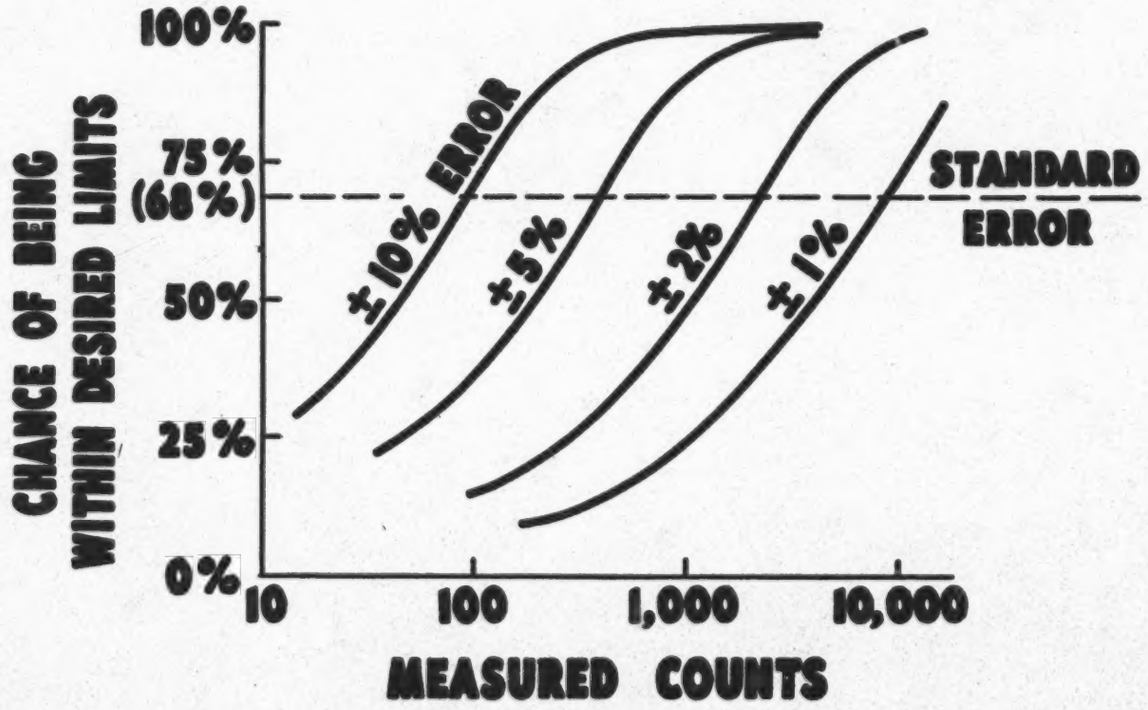
USAEC-ID-205A

CONSIDERATIONS
IN
RADIOACTIVITY MEASUREMENTS



USAEC-ID-206A

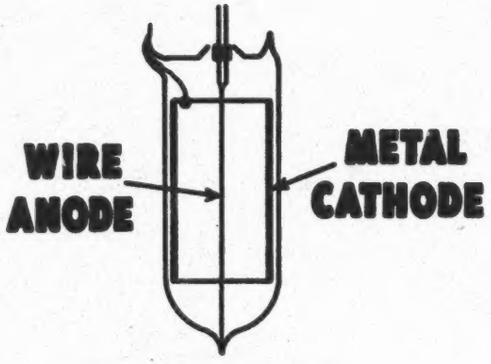
NEED FOR LARGE COUNTS
TO REDUCE ERROR



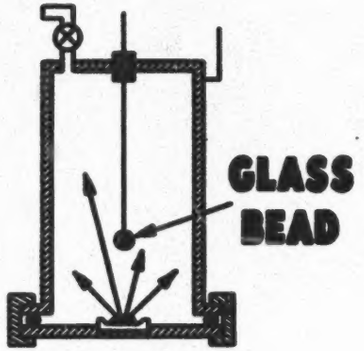
HIGH PROBABILITY OF LOW ERROR REQUIRES HIGH COUNT

USAEC-ID-207A

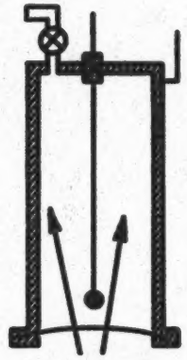
TYPES OF GEIGER-MÜLLER COUNTERS



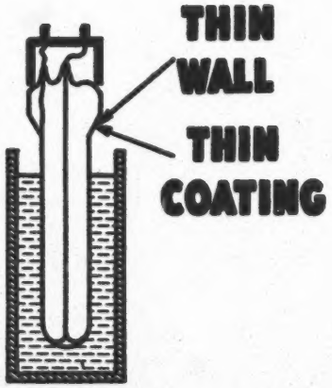
COMMON TYPE



INTERNAL COUNTER

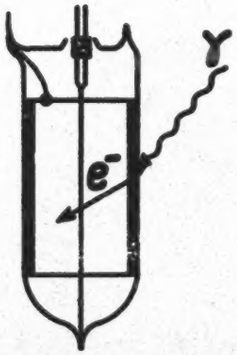


THIN WINDOW β COUNTER



IMMERSION β COUNTER

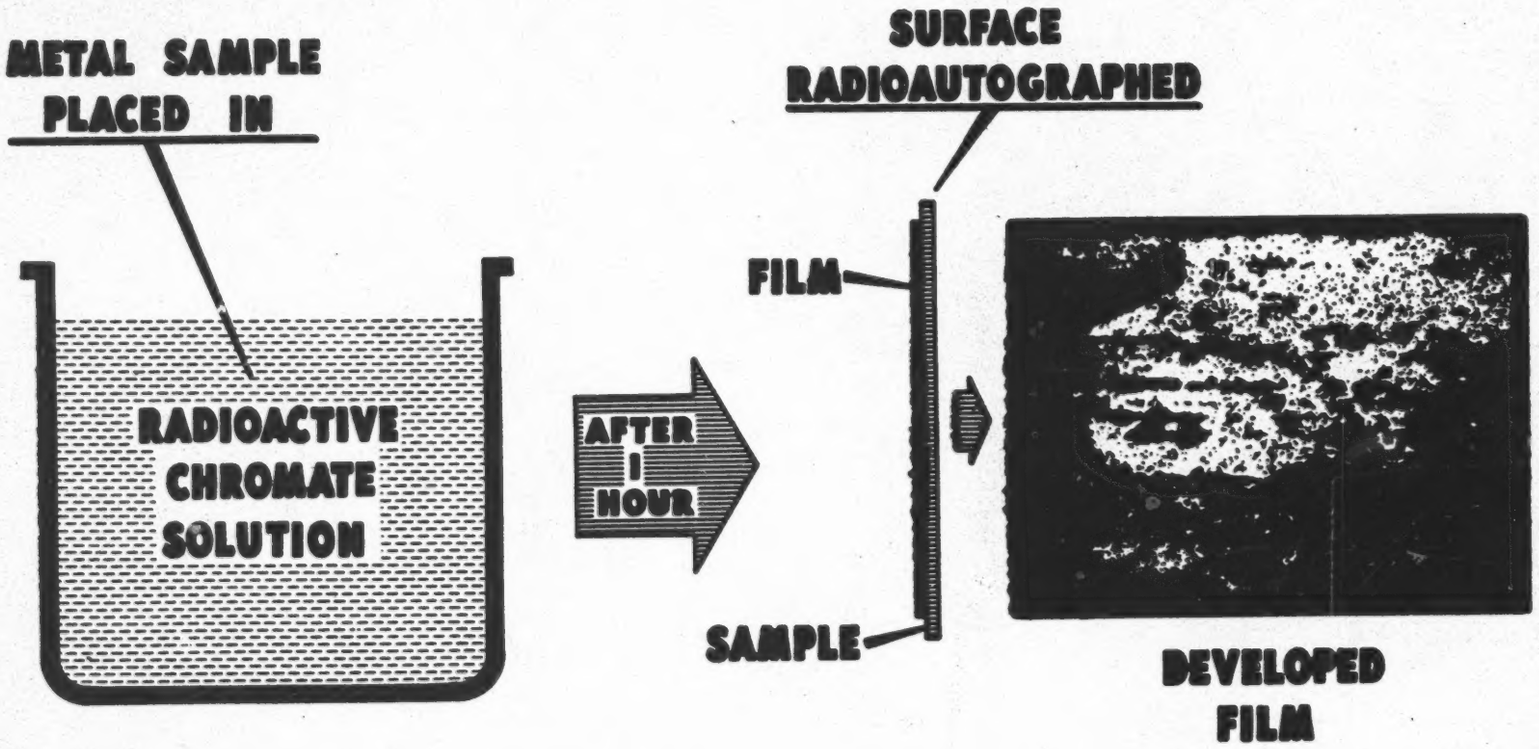
TISSUE PROBE



BISMUTH WALL COUNTER

USAEC-ID-213A

MECHANISM OF CHROMATE INDUCED PASSIVITY

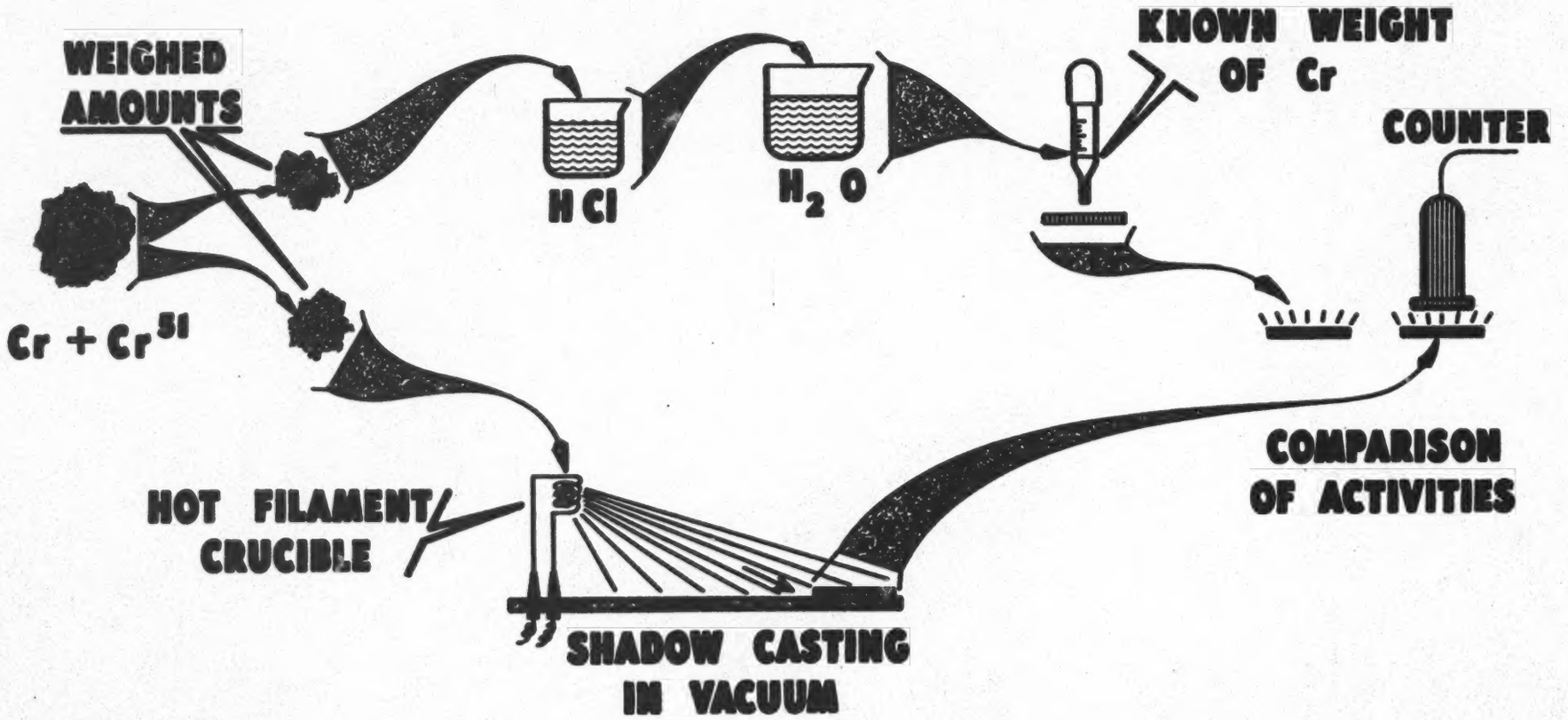


Cr 51 CONCENTRATES AT POINTS OF CORROSION—

SUPPORTING OXIDE FILM THEORY

USAEC-ID-218A

DETERMINATION OF DEPOSIT THICKNESS
IN VACUUM-CAST FILMS



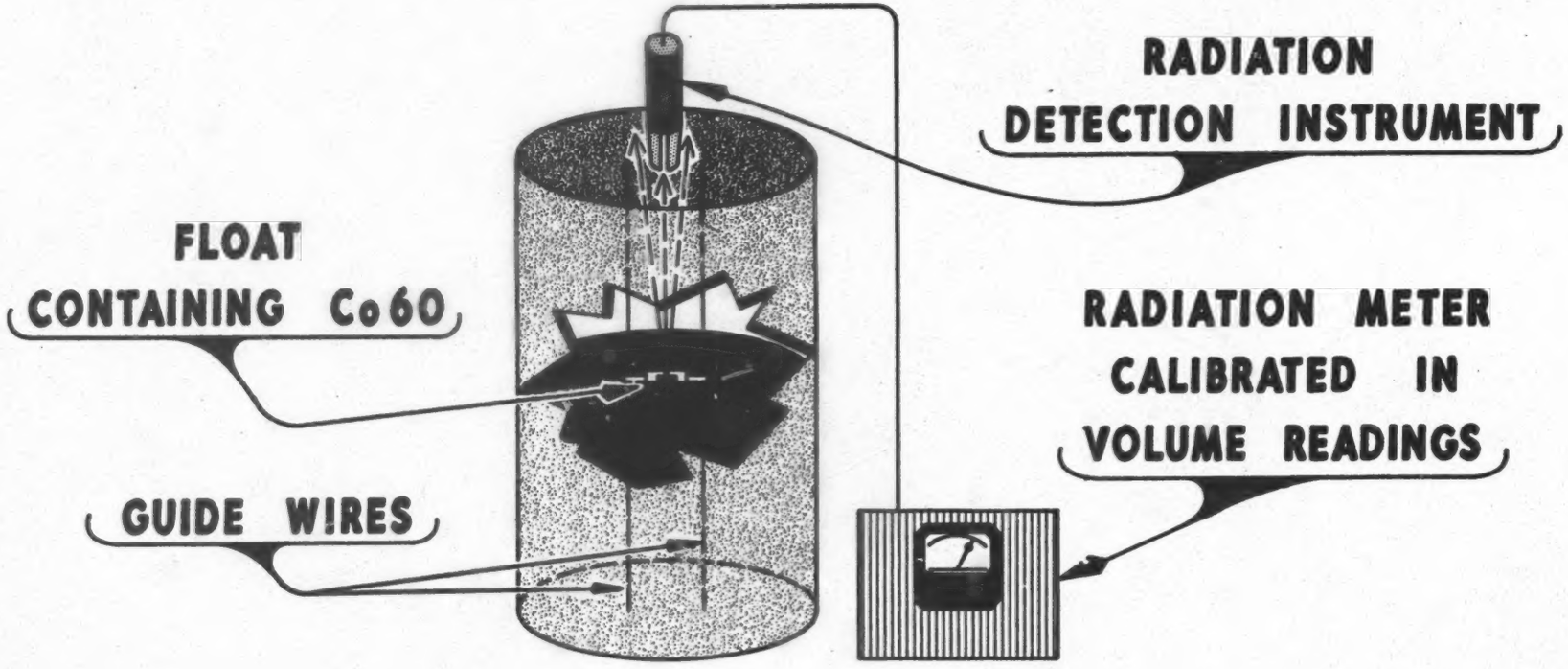
- MEASURES TO TRILLIONTH OF AN INCH
- CALIBRATES DISTRIBUTION FROM CRUCIBLE

USAEC-ID-223A

ILLUSTRATIONS OF ISOTOPE APPLICATIONS IN INDUSTRY

RADIOACTIVE COBALT – Co^{60}

FOR LIQUID LEVEL GAGE



ADVANTAGES:

1 - CONTINUOUS RECORDING

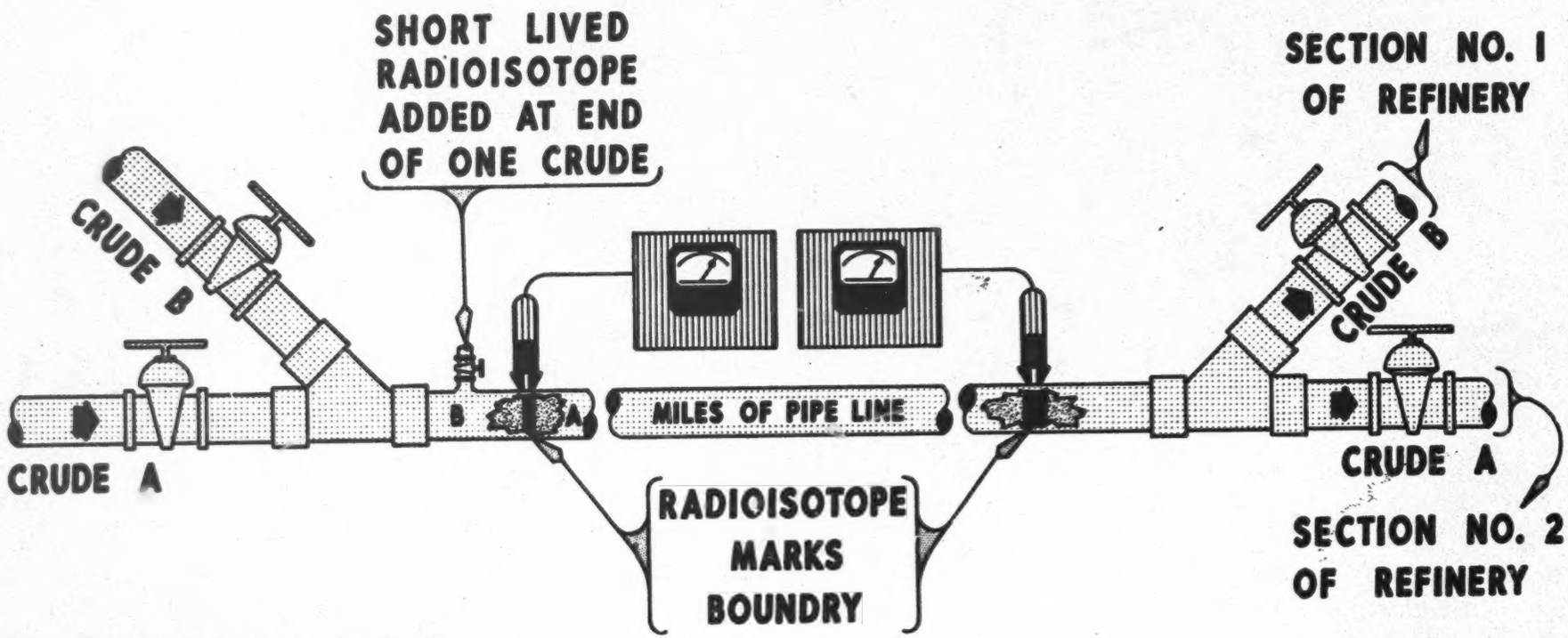
2 - MEASUREMENT MADE ON CLOSED SYSTEM

3 - ADAPTABLE TO AUTOMATIC CONTROL

USAEC-ID-198

RADIOACTIVE ISOTOPES

FOR TRACING OIL FLOW IN PIPE LINES



ADVANTAGES:

1 - RADIOACTIVE "MARKER" CAN BE TRACED OVER LONG DISTANCE

2 - "MARKER" SPREADS TO ONLY SMALL OIL VOLUME

3 - PERMITS SEPARATION OF CRUDES WITH MINIMUM OF LOSS

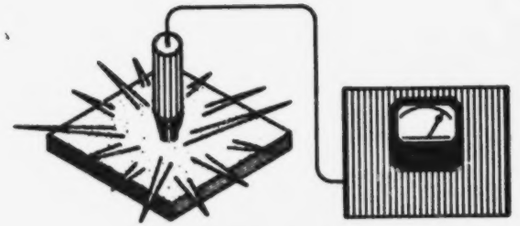
4 - METHOD QUICK AND REQUIRES NO SAMPLING

USAEC-ID-208

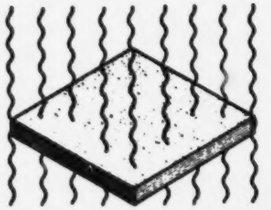
RADIOACTIVE ISOTOPES

FOR STUDYING SOLID DIFFUSION

METAL SPECIMEN
PLATED WITH ISOTOPE

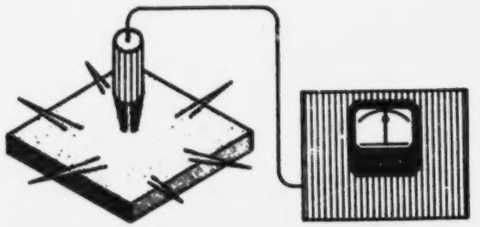


SURFACE ACTIVITY
MEASURED



SPECIMEN HEATED

RADIOACTIVE ATOMS
DIFFUSE INTO INTERIOR



DECREASED SURFACE
ACTIVITY MEASURED

ADVANTAGES:

1 - GIVES ACCURATE MEASURE OF RATE AND AMOUNT OF DIFFUSION

2 - QUICKER AND MORE RELIABLE THAN OTHER METHODS

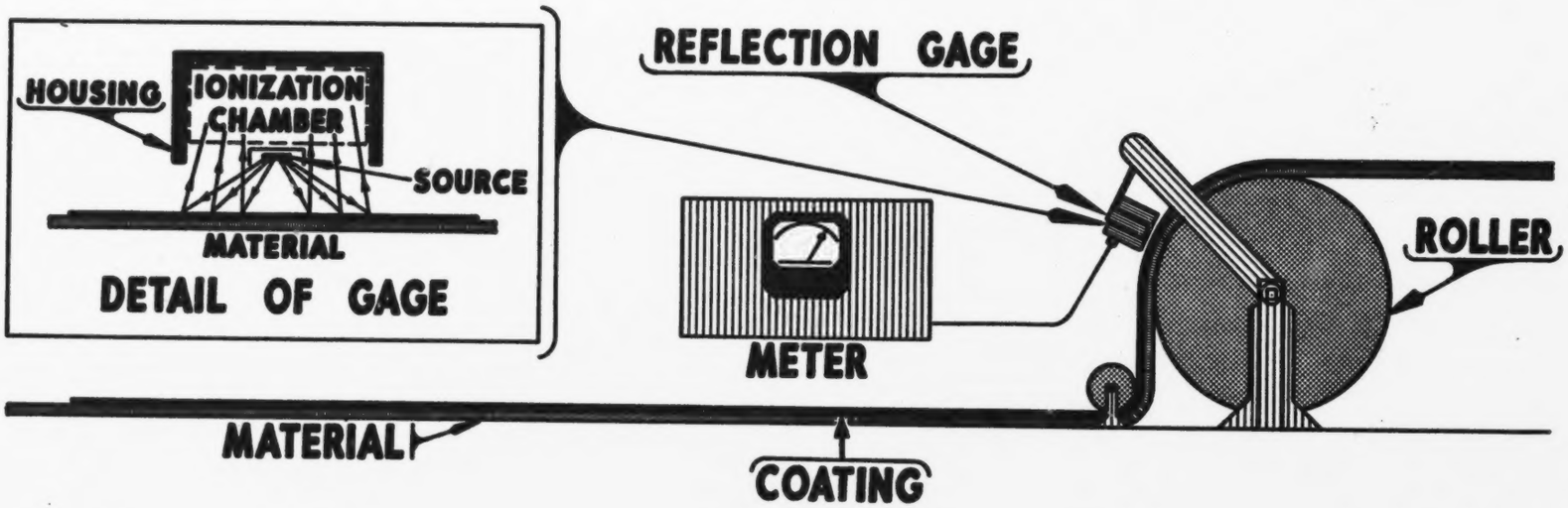
3 - ONLY METHOD SPECIFIC ENOUGH TO MEASURE SELF-DIFFUSION

USAEC-ID-210

3

RADIOACTIVE SOURCE

FOR REFLECTION (BACKSCATTERING) THICKNESS GAGE



ADVANTAGES:

1- CAN MEASURE THICKNESS OF COATING AND/OR MATERIAL

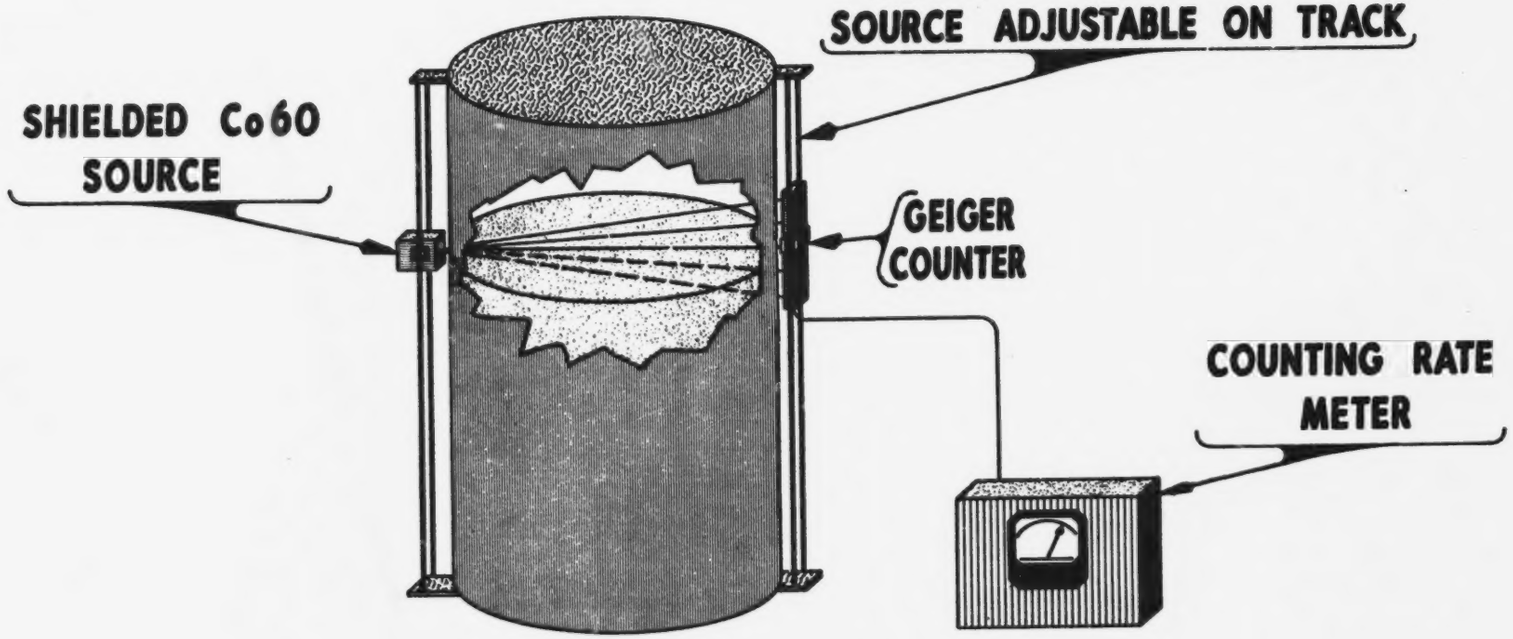
2- MEASUREMENT MADE FROM ONE ACCESSIBLE SIDE

3- CAN MEASURE A VARIETY OF MATERIALS WITH ONE CALIBRATION

USAEC-ID-220

RADIOACTIVE COBALT – Co^{60}

FOR INDICATING LIQUID HEIGHT



ADVANTAGES:

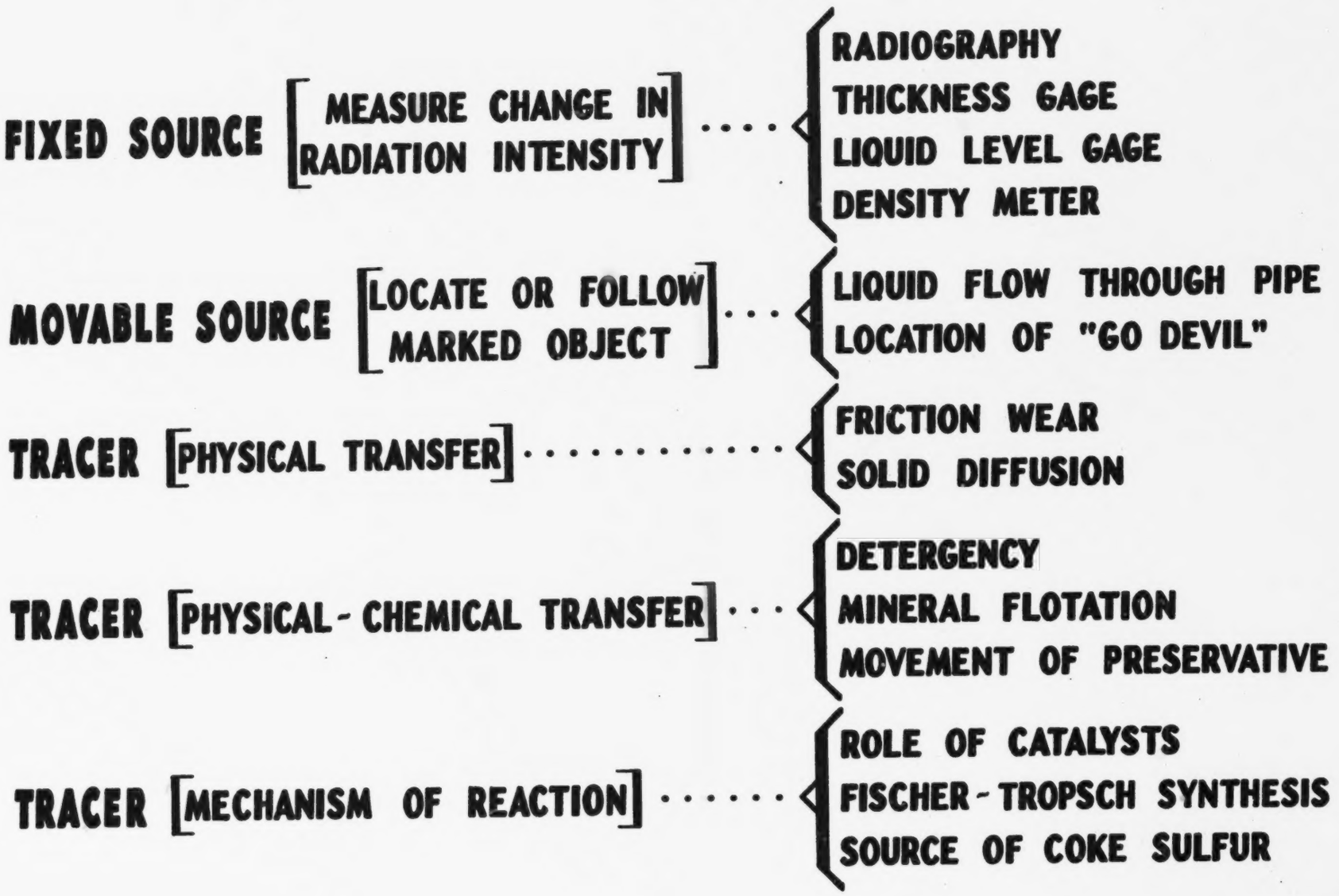
1 - GAGE NOT AFFECTED BY CORROSION AND TEMPERATURE

2 - CAN BE OPERATED BY NON-TECHNICAL PERSONNEL

3 - ADAPTABLE TO AUTOMATIC RECORDING AND CONTROL OF LIQUID LEVEL

USAEC-ID-284

RADIOISOTOPES IN INDUSTRY



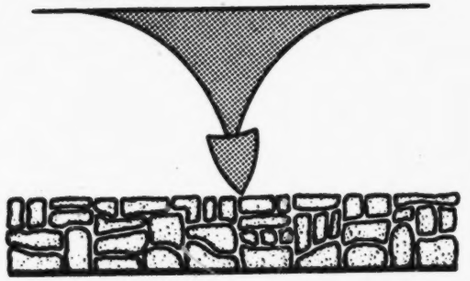
USAEC-ID-427

RADIOACTIVE CALCIUM — Ca45

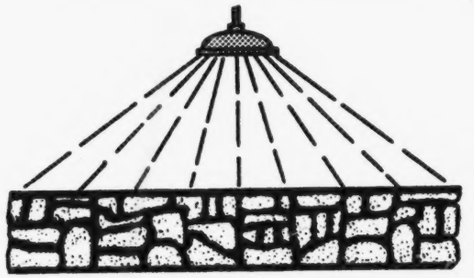
FOR TESTING

PAVING ASPHALTS

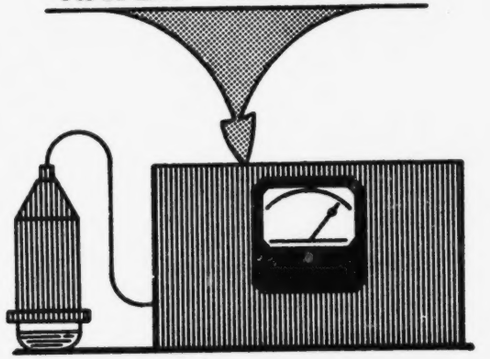
RADIOACTIVE $CaCl_2$ PUT ON STONE PRIOR TO COATING WITH ASPHALT



ASPHALT COATED STONE SPRAYED WITH WATER



RADIOACTIVITY OF WATER MEASURED



INDICATES

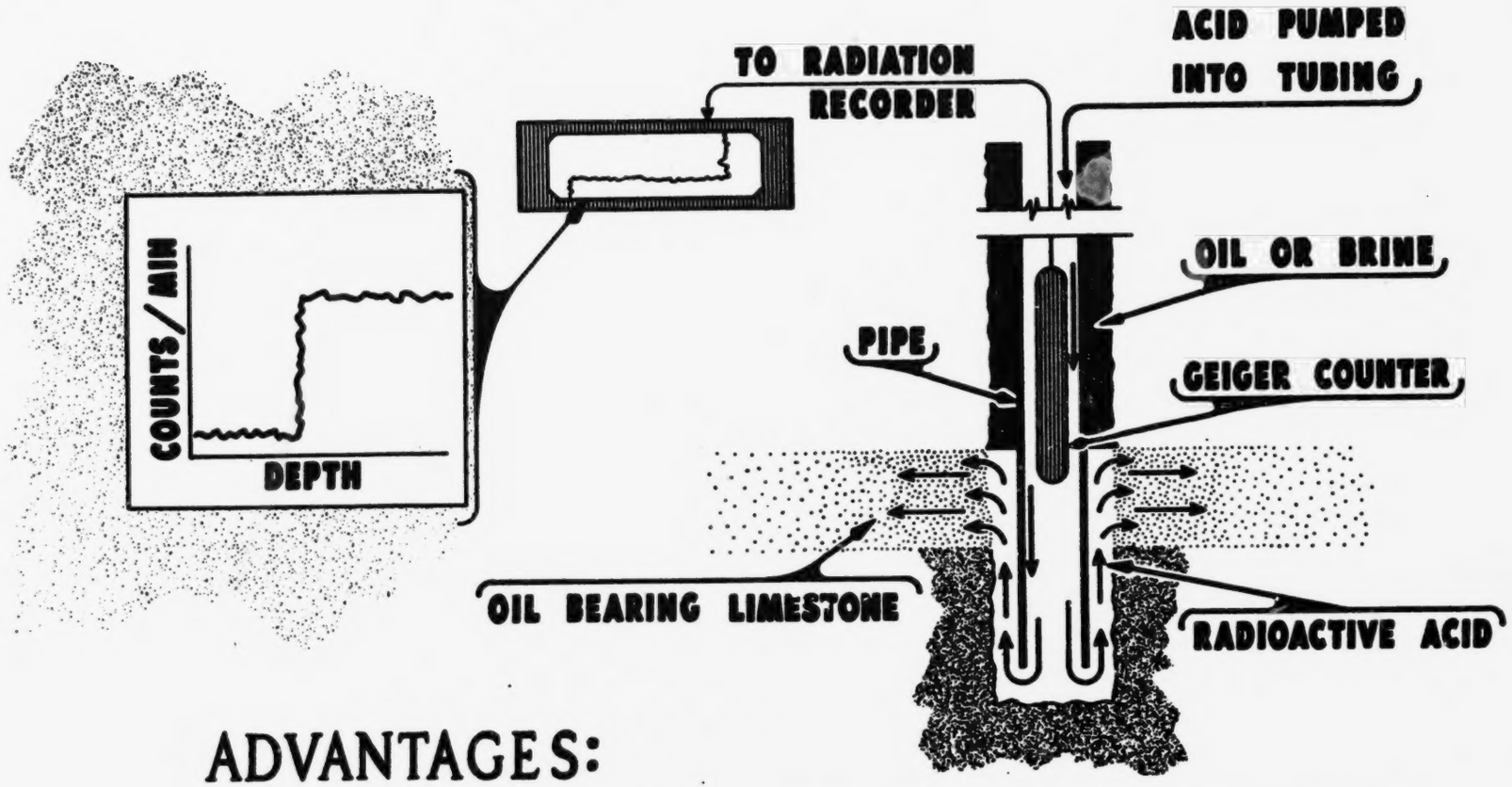
1 - BONDING BETWEEN ASPHALT AND STONE

2 - DURABILITY OF ROAD MATERIALS

3 - BLENDS FOR BETTER PAVING

USAEC-ID-475

RADIOACTIVE ISOTOPES
FOR CONTROL OF OIL WELL ACIDIZING



ADVANTAGES:

1 - PERMITS CONTROLLING SITE OF ACID ACTION
2 - INCREASES EFFICIENCY OF OIL PRODUCTION
3 - SAVES TIME AND MONEY
4 - LESS HAZARDOUS THAN REMOVING PIPE

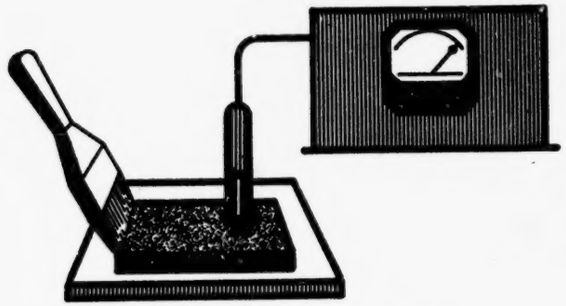
USAEC-ID-3A

RADIOACTIVE ISOTOPES

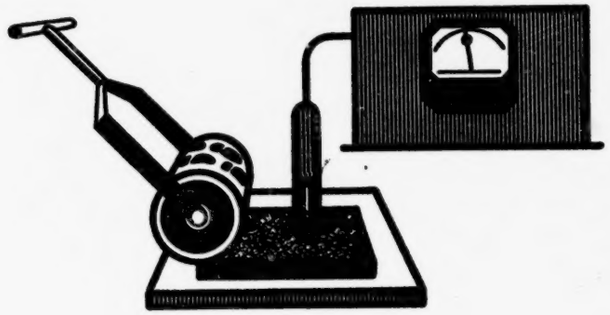
FOR TESTING WEAR RESISTANCE OF FLOOR WAX

① ADD RADIOACTIVE COMPOUND TO WAX

② APPLY WAX TO LINOLEUM AND MEASURE ACTIVITY



③ SUBJECT WAX TO WEAR AND MEASURE ACTIVITY



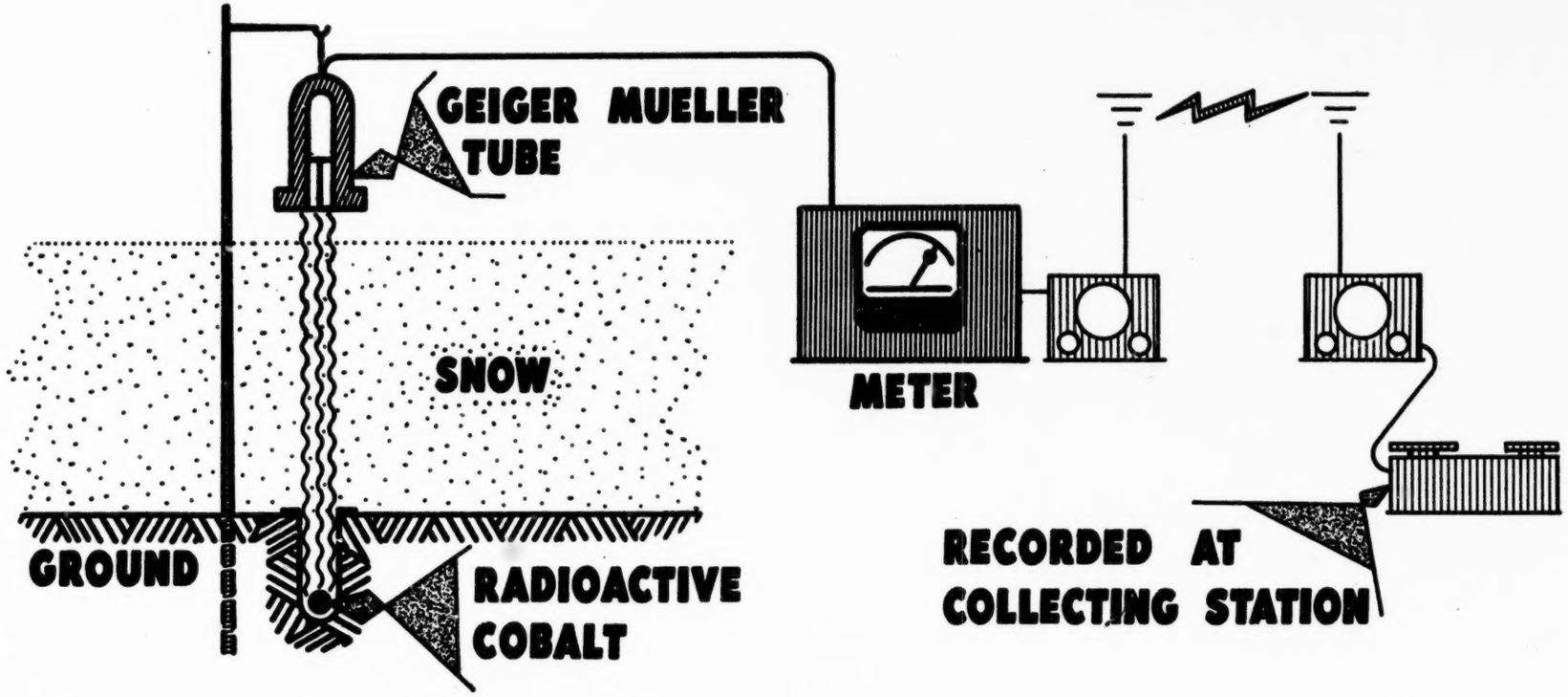
ADVANTAGES

1 - QUANTITATIVE MEASUREMENT OF WEAR
2 - MEASURES EARLY PHASES OF WEAR
3 - MEASURES EXTREMELY MINUTE AMOUNTS

USAEC-ID-4A

RADIOACTIVE COBALT – Co 60

FOR MEASURING WATER CONTENT OF SNOWFALL



ADVANTAGES:

1 - MEASURES AMOUNT OF WATER DIRECTLY

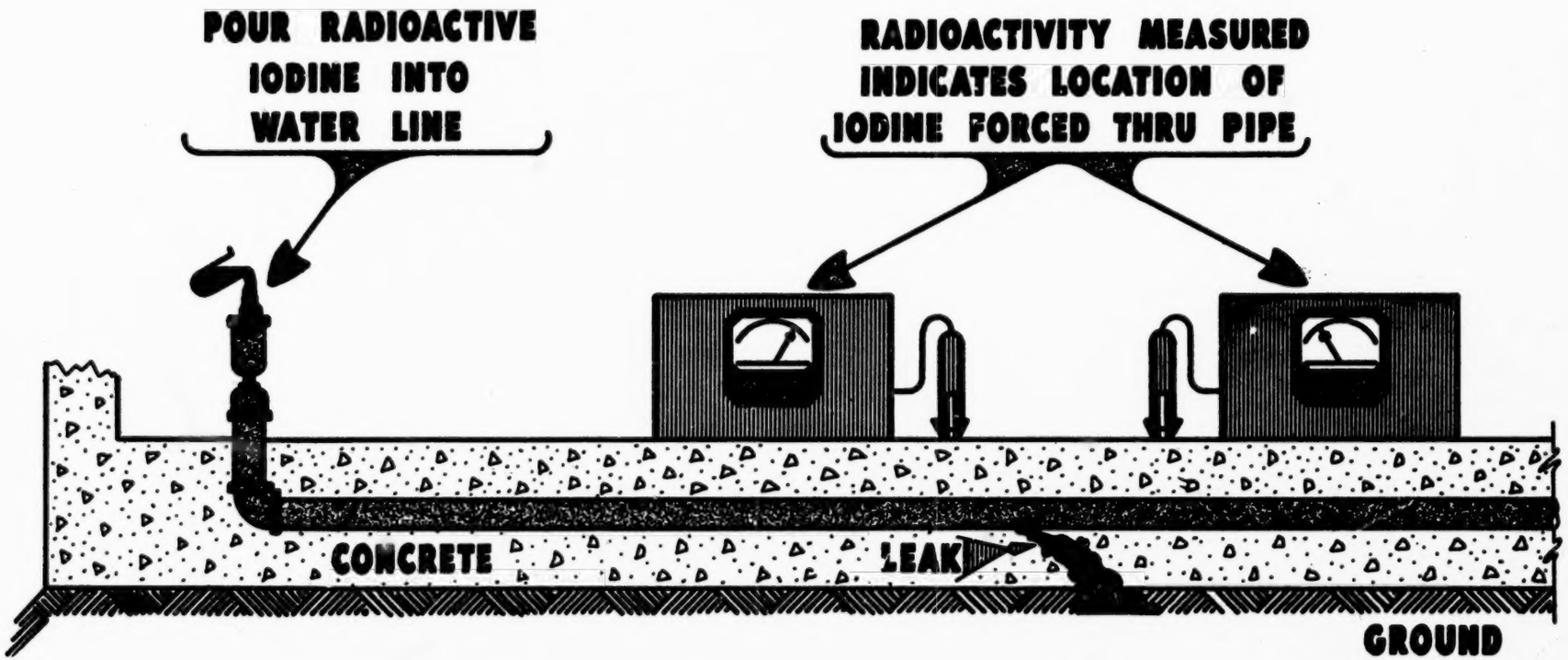
2 - MEASUREMENTS TAKEN REMOTELY

3 - HIGHER DEGREE OF ACCURACY

USAEC-ID-7A

RADIOACTIVE IODINE – I·131

FOR DETECTING LEAKS IN WATER LINES



ADVANTAGES:

1 - NOT NECESSARY TO REMOVE FLOORS

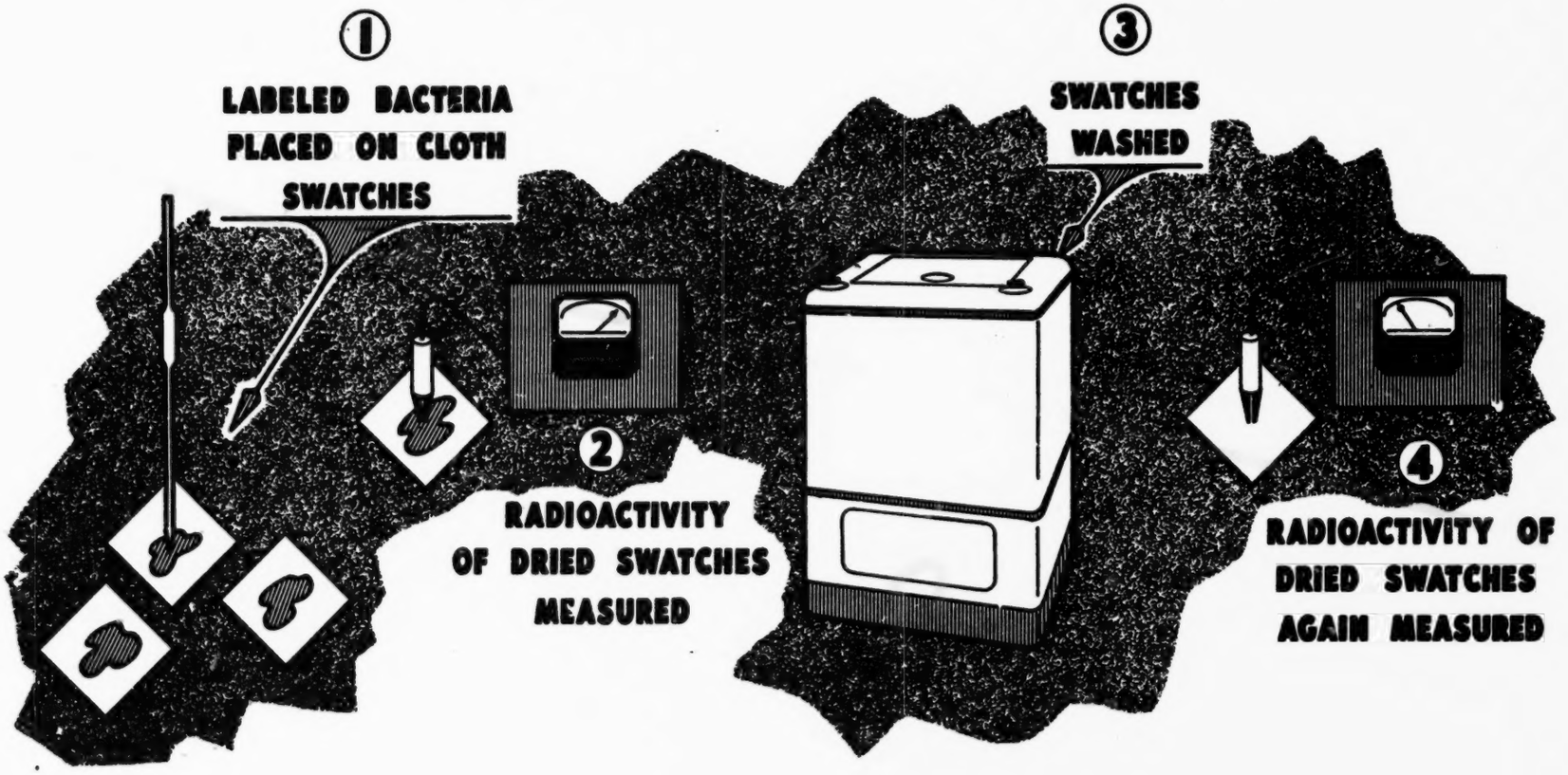
2 - LESS COSTLY AND MORE CONVENIENT

3 - SHORT HALF-LIFE --- NO RESIDUAL ACTIVITY

USAEC-ID·6A

TEST FOR WASHING EFFICIENCY

USING RADIOACTIVE PHOSPHORUS - P32



SHOWS:

1 - EFFICIENCY OF WASHING PROCEDURES FOR REMOVING BACTERIA

2 - COMPARATIVE EFFICIENCIES OF VARIOUS DETERGENTS

3 - AMOUNT OF CROSS CONTAMINATION

USAEC-ID 25A

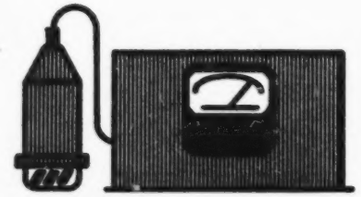
TEST ON COTTON DETERGENCY
WITH
RADIOACTIVE CALCIUM - Ca 45

① DETERGENT AND LABELED CALCIUM BICARBONATE ADDED TO WASH WATER

② COTTON SWATCHES INTRODUCED

③ SWATCHES WASHED WITH HEAT AND AGITATION APPLIED

④ RADIOACTIVITY OF RINSED AND DRIED SWATCHES MEASURED



INDICATES:

1 - AMOUNT OF CALCIUM ADSORBED ON CLOTH

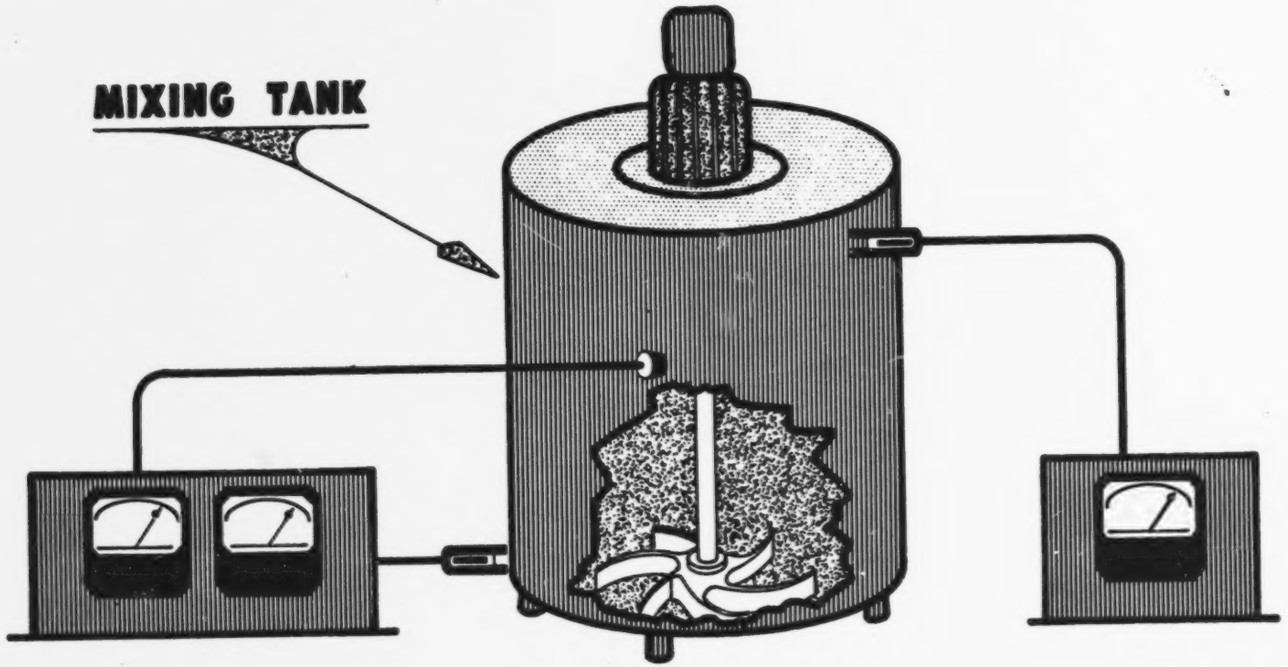
2 - CALCIUM ADSORPTION DEPENDS ON TYPE OF DETERGENT

3 - CORRELATION BETWEEN CALCIUM UPTAKE AND DETERGENT ACTION

USAEC-ID28A

RADIOACTIVE ISOTOPES

FOR DETERMINING THOROUGHNESS OF MIXING



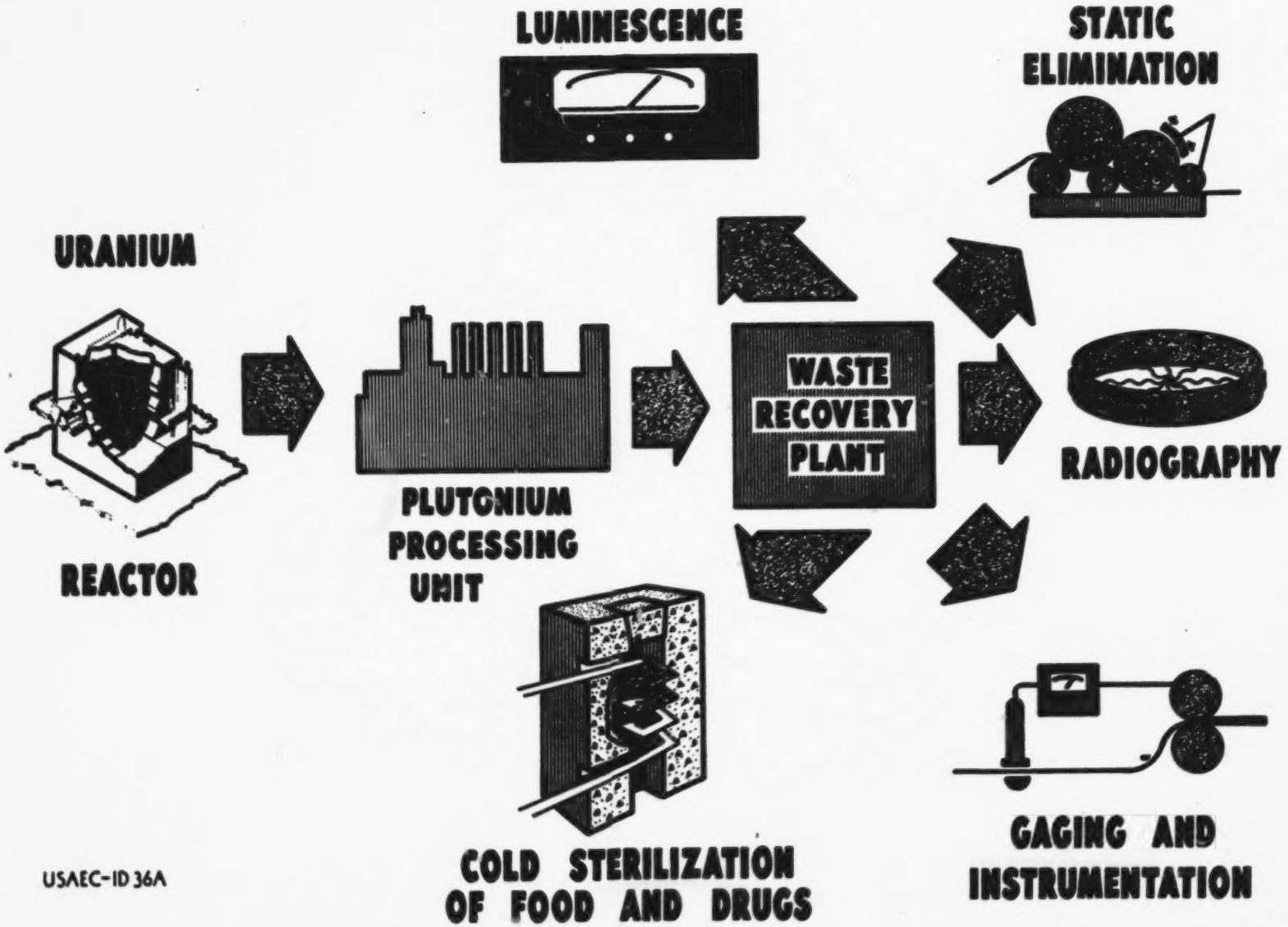
ADVANTAGES:

1 - UNIFORMITY OF MIXING EASILY ASSURED

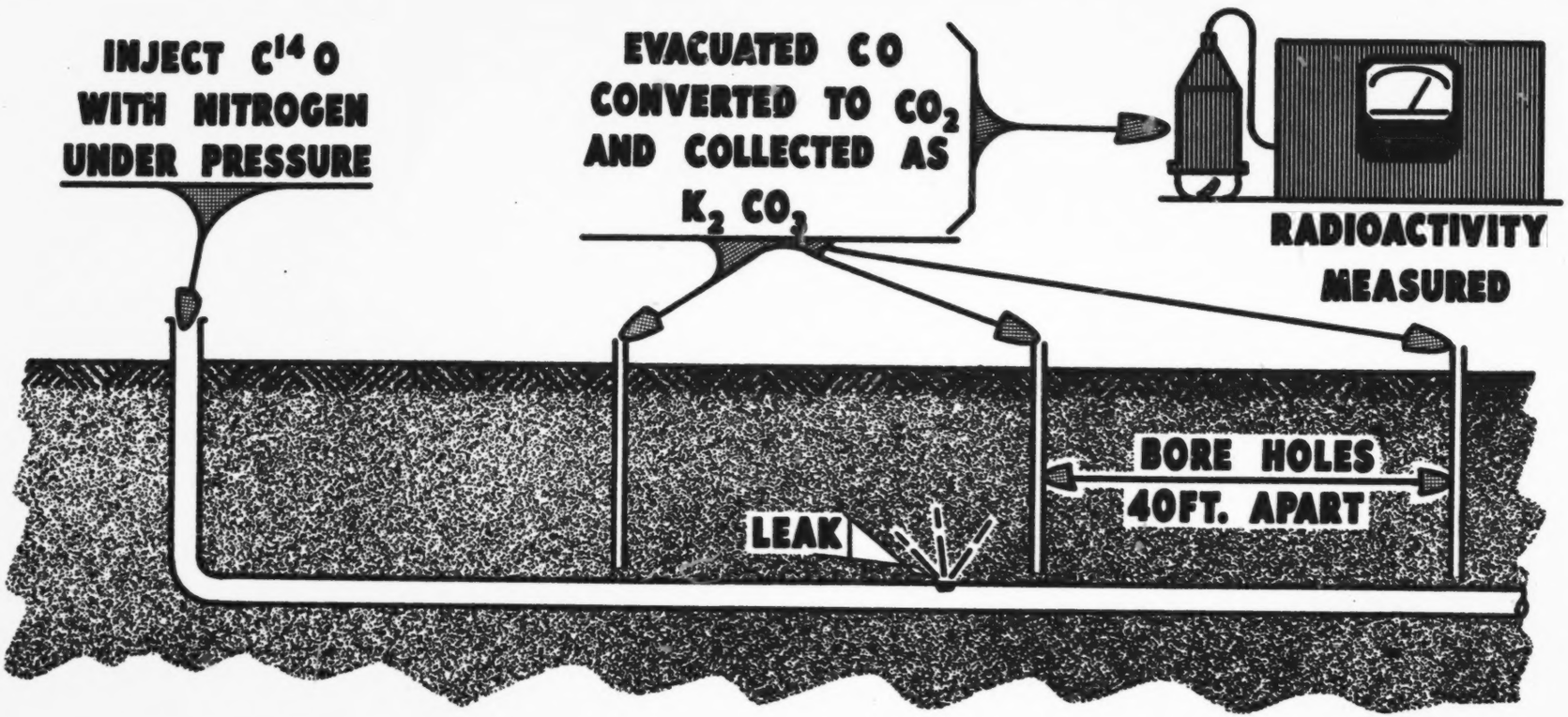
2 - EXCESSIVE MIXING TIME ELIMINATED

USAEC-ID-34A

SOME USES OF FISSION PRODUCTS



LOCATING LEAKS IN UNDERGROUND CONDUITS
WITH
RADIOACTIVE CARBON — C14



ADVANTAGES:

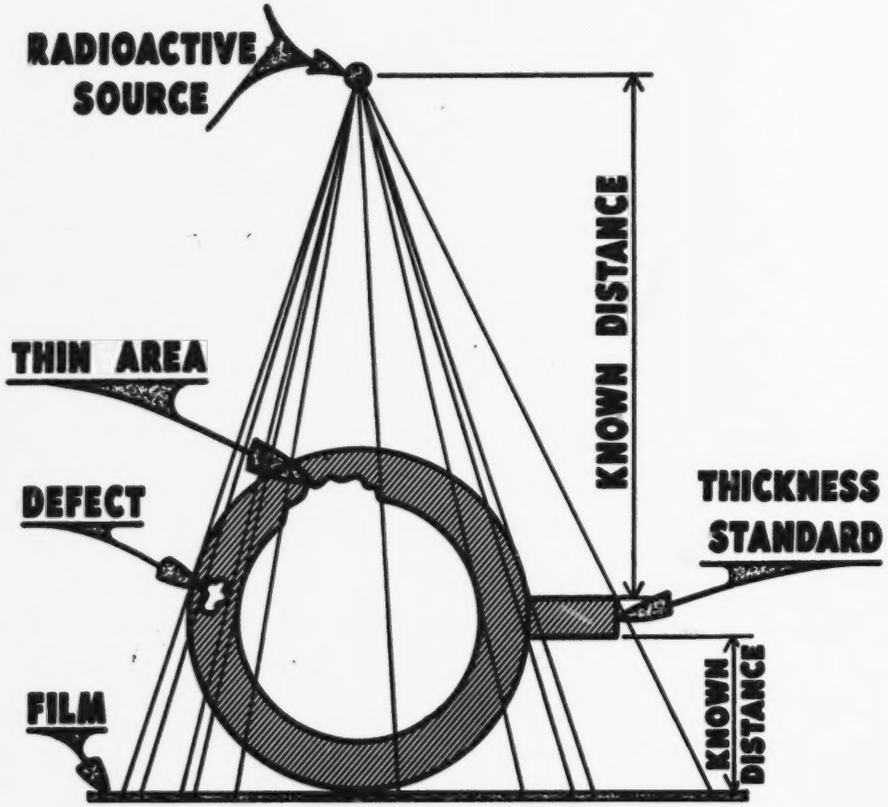
1—GREAT SENSITIVITY

2—SIMPLE AND INEXPENSIVE

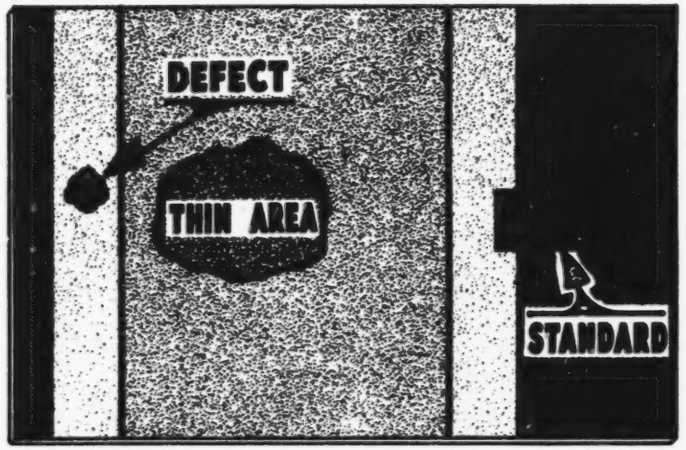
3—NO INTERRUPTION TO NORMAL SERVICE

USAEC-ID41A

MEASURING THICKNESS AND DEFECTS OF METAL CASTINGS WITH RADIOISOTOPES



RADIOGRAPH



DEVELOPED FILM

ADVANTAGES:

1 - VERSATILE AND RELIABLE INSPECTION

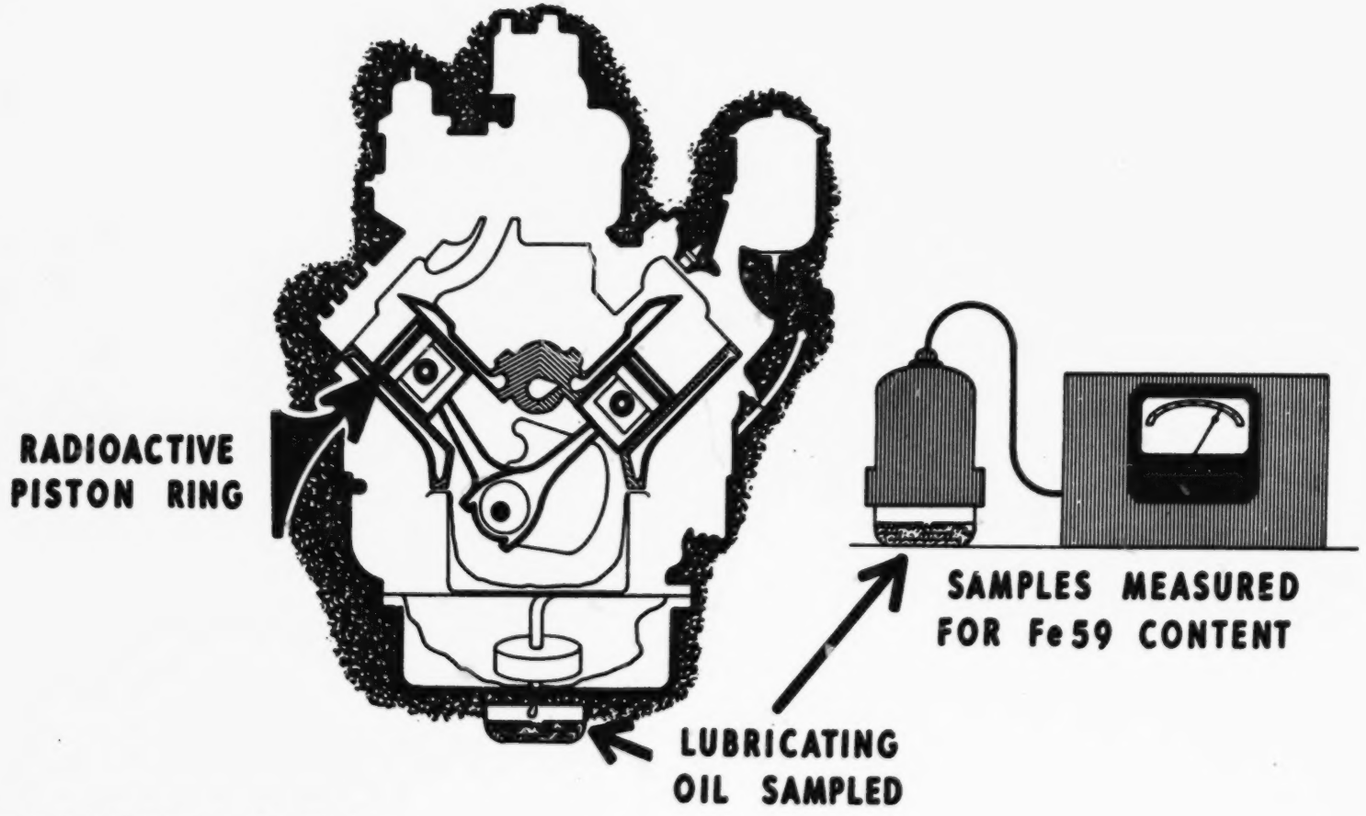
2 - INSPECTION MADE WITHOUT DISMANTLING

3 - VERY HIGH ACTIVITY SOURCES AVAILABLE AT LOW COST

USAEC-ID-59A

RADIOACTIVE IRON – Fe 59

FOR FRICTION AND LUBRICATION STUDIES



ADVANTAGES:

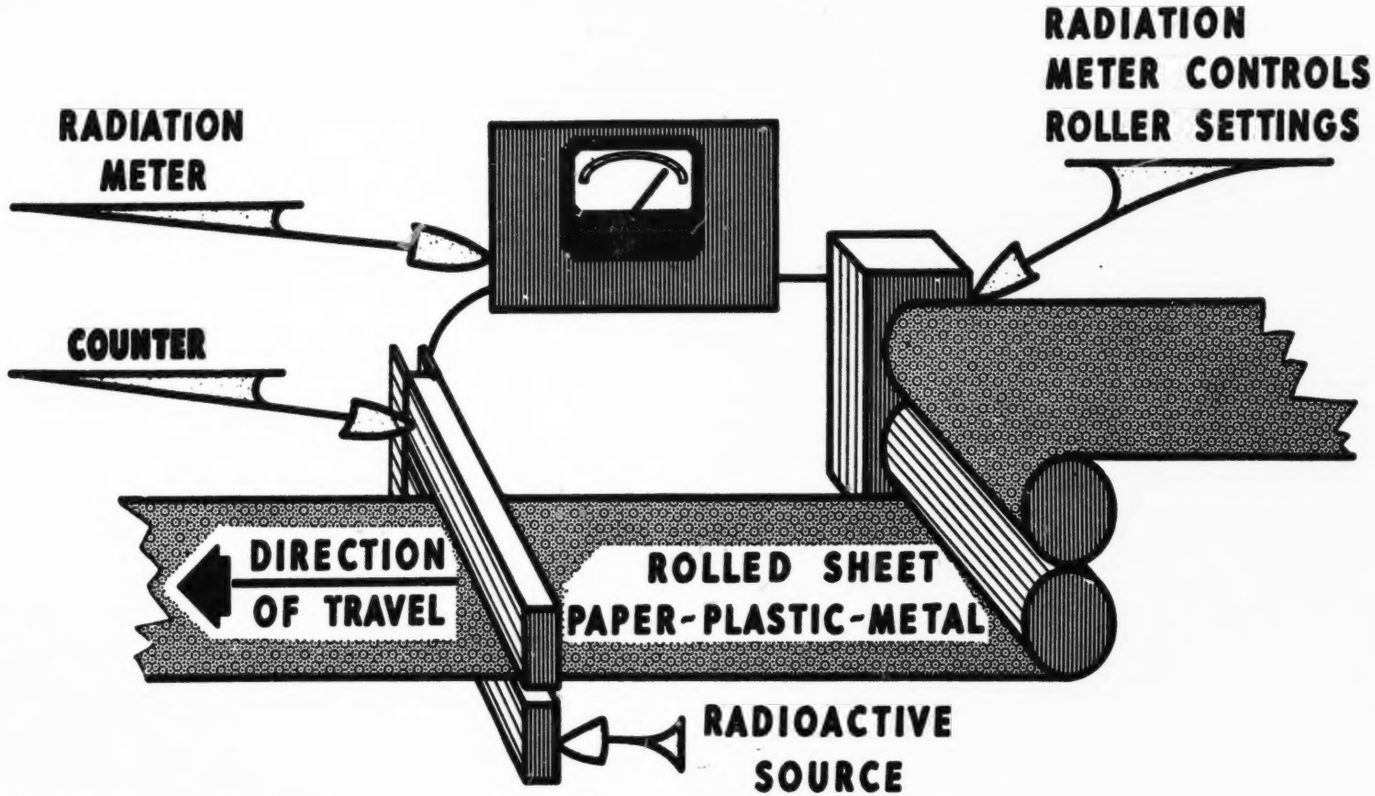
1 - TRANSFER OF METAL MEASURED TO $\frac{1}{100,000}$ OUNCE

2 - OIL SAMPLED DURING OPERATION OF MOTOR

3 - RAPID - SIMPLE - ECONOMICAL

USAEC-ID-68A

RADIOACTIVE SOURCE
FOR GAGING THICKNESS



ADVANTAGES:

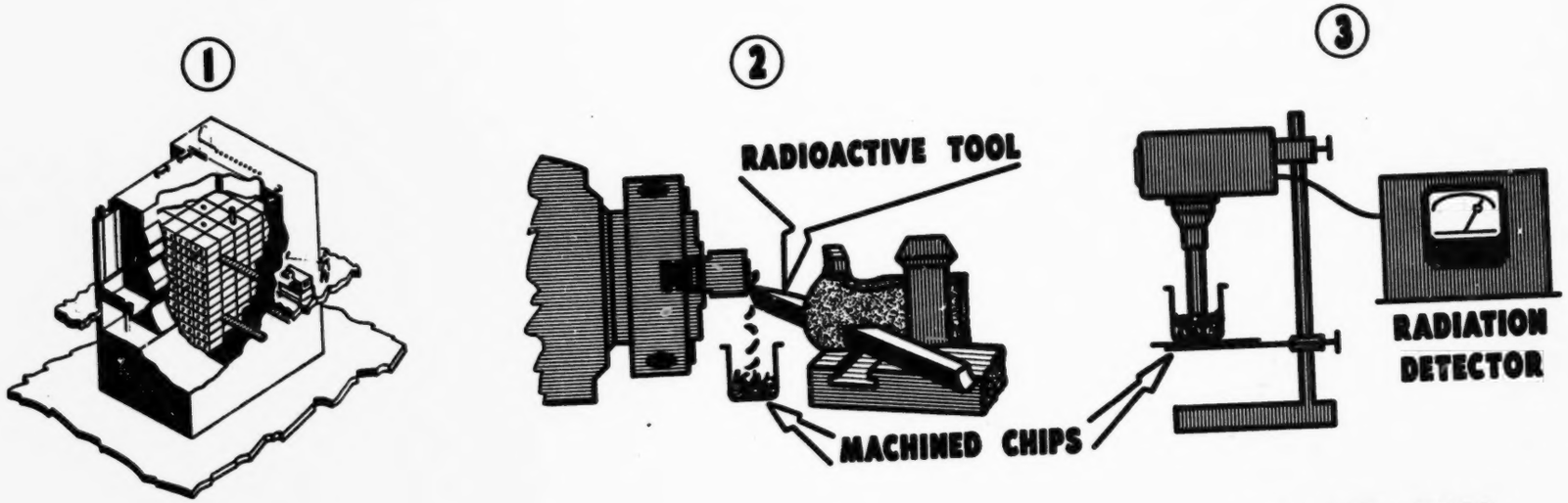
1-RADIATION SOURCE SELECTED TO SUIT MATERIAL
2-NO CONTACT-NO TEARING-NO MARKING MATERIAL
3-RAPID AND RELIABLE

USAEC-ID-69A

MEASURING CUTTING TOOL WEAR AND LIFE

BY

RADIOACTIVITY TESTS



CUTTING TOOL IRRADIATED IN NUCLEAR REACTOR

RADIOACTIVE TOOL USED FOR MACHINING

MACHINED CHIPS MEASURED FOR RADIOACTIVITY

ADVANTAGES:

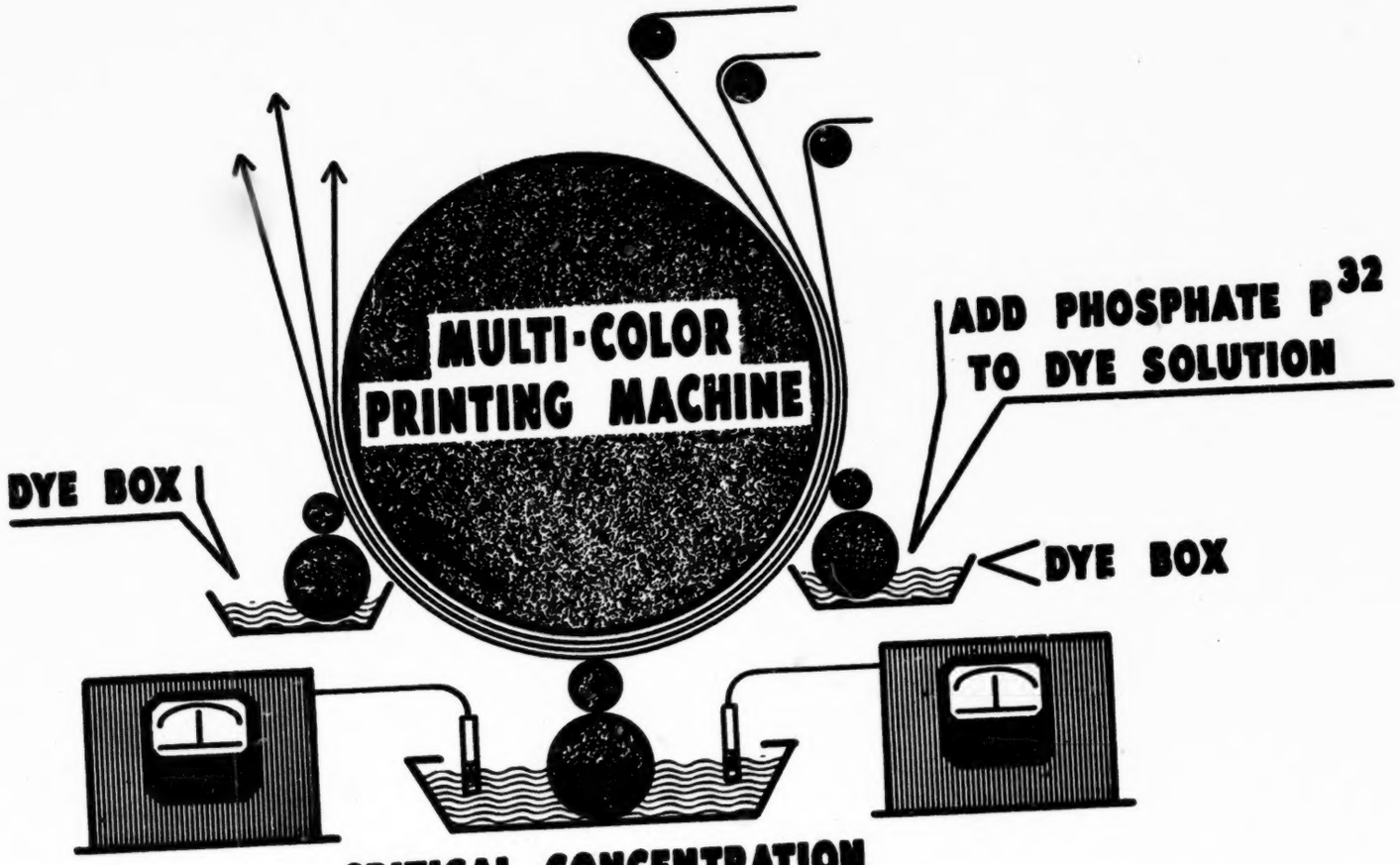
1-MORE REPRODUCIBLE AND SENSITIVE THAN OTHER TESTS

2-FASTER AND MORE EFFICIENT

3-YIELDS KNOWLEDGE OF WEAR PROCESS

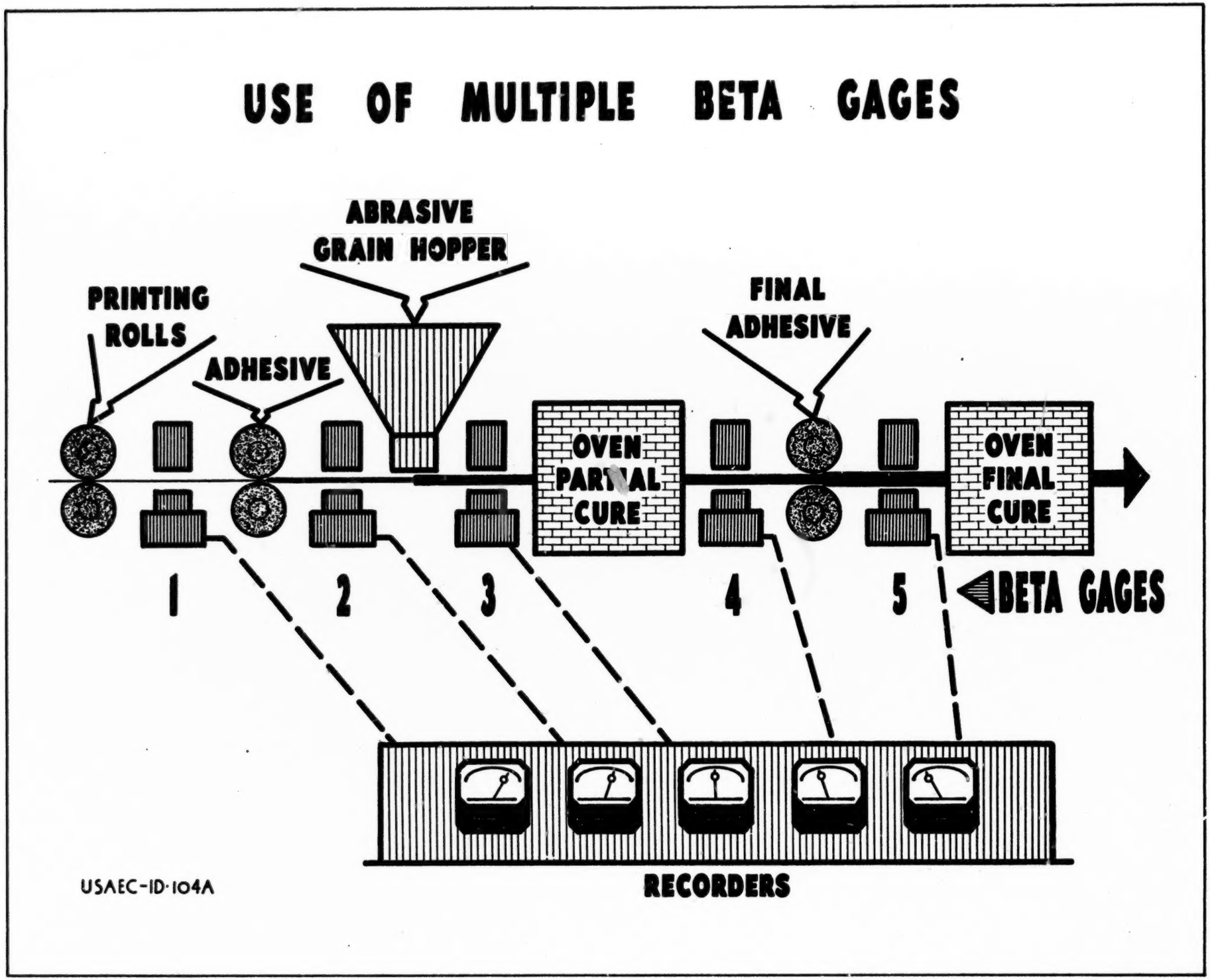
USAEC-ID-87A

DETECTION OF DYE MIGRATION
WITH
RADIOACTIVE PHOSPHORUS - P32

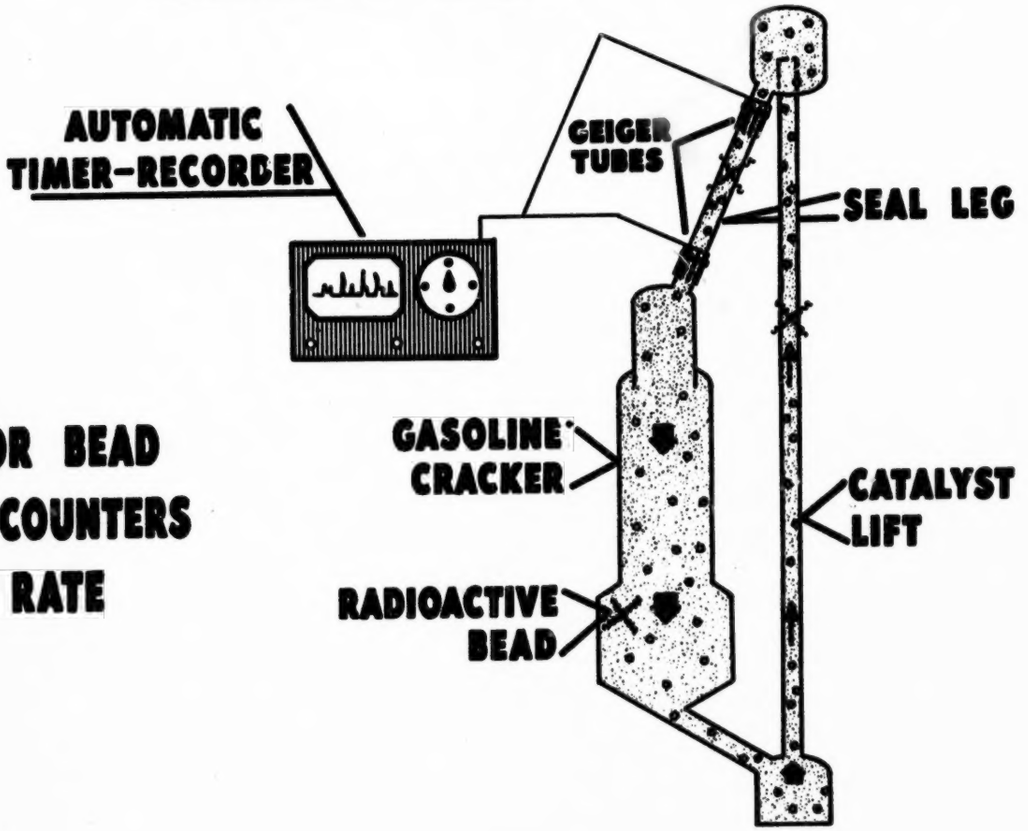


CRITICAL CONCENTRATION
OF MIGRANT "PIRATE COLOR"
REVEALED BY GEIGER COUNTER

USAEC-ID-103A


USE OF MULTIPLE BETA GAGES
ABRASIVE GRAIN HOPPER
PRINTING ROLLS
ADHESIVE
FINAL ADHESIVE
OVEN PARTIAL CURE
OVEN FINAL CURE
1
2
3
4
5
BETA GAGES
RECORDERS
USAEC-ID-104A

CONTROL OF CATALYST FLOW RATE
USING
RADIOACTIVE BEADS



TIME REQUIRED FOR BEAD
TO PASS BETWEEN COUNTERS
MEASURES FLOW RATE

ADVANTAGES:

1—IMMEDIATE INDICATION OF IMPROPER OPERATION

2—NO INTERFERENCE WITH PRODUCTION

3—POSSIBLE AUTOMATIC ADJUSTMENT OF FLOW RATE

USAEC-ID-147A

ISOTOPES FOR RADIOGRAPHY

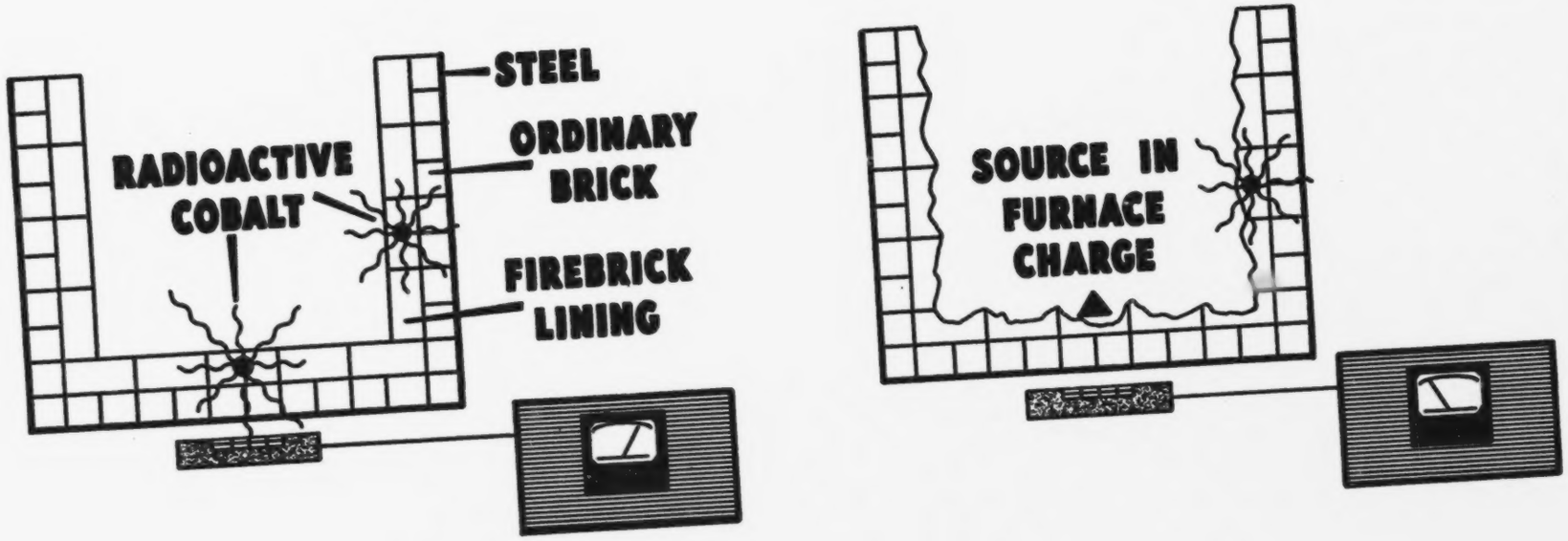
ISOTOPE	HALF-LIFE	PRINCIPAL GAMMA RAY ENERGIES - Mev	APPROX. SPEC. ACT.	APPROX. γ-RAY OUTPUT / CURIE r/hr/ft	TYPE OF USE
Co 60	5.3 y	1.1, 1.3	7 c/g — NOW 35 c/g — 1954	14.4	HEAVY CASTINGS THICK WELDMENTS
Ta 182	117 d	1.1, 1.2	1.5 c/g GREATER IF NEEDED	6.7	HEAVY CASTINGS THICK WELDMENTS
Cs 137	37 y	0.66	20 c/g - 1955 (Cs_2SO_4)	3.5	—
Ir 192	75 d	0.3, 0.5	2.5 c/g - NOW 30 c/g - 1954	3.0	PIPE LINES LIGHT ALLOYS THIN SECTIONS
Tm 170	127 d	0.085	SERVICE IRRADIATION	—	LIGHT ALLOYS THIN SECTIONS

USAEC-ID-149A

MEASURING WEAR OF FIREBRICK LINING

USING

RADIOACTIVE COBALT — Co^{60}



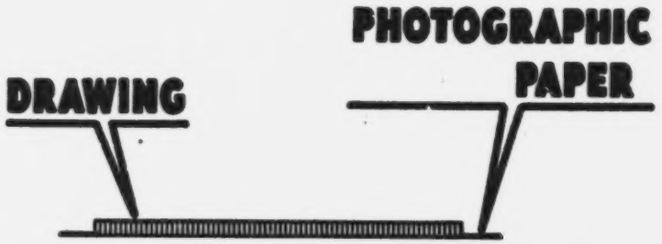
ADVANTAGES:

- PERMITS NORMAL OPERATION
- WARNS OF INCIPIENT FAILURE

USAEC-ID-217A

ELECTRON PRINTING
WITH RADIOISOTOPES

ARTIST DRAWS, PAINTS OR SKETCHES WITH RADIOACTIVE INK



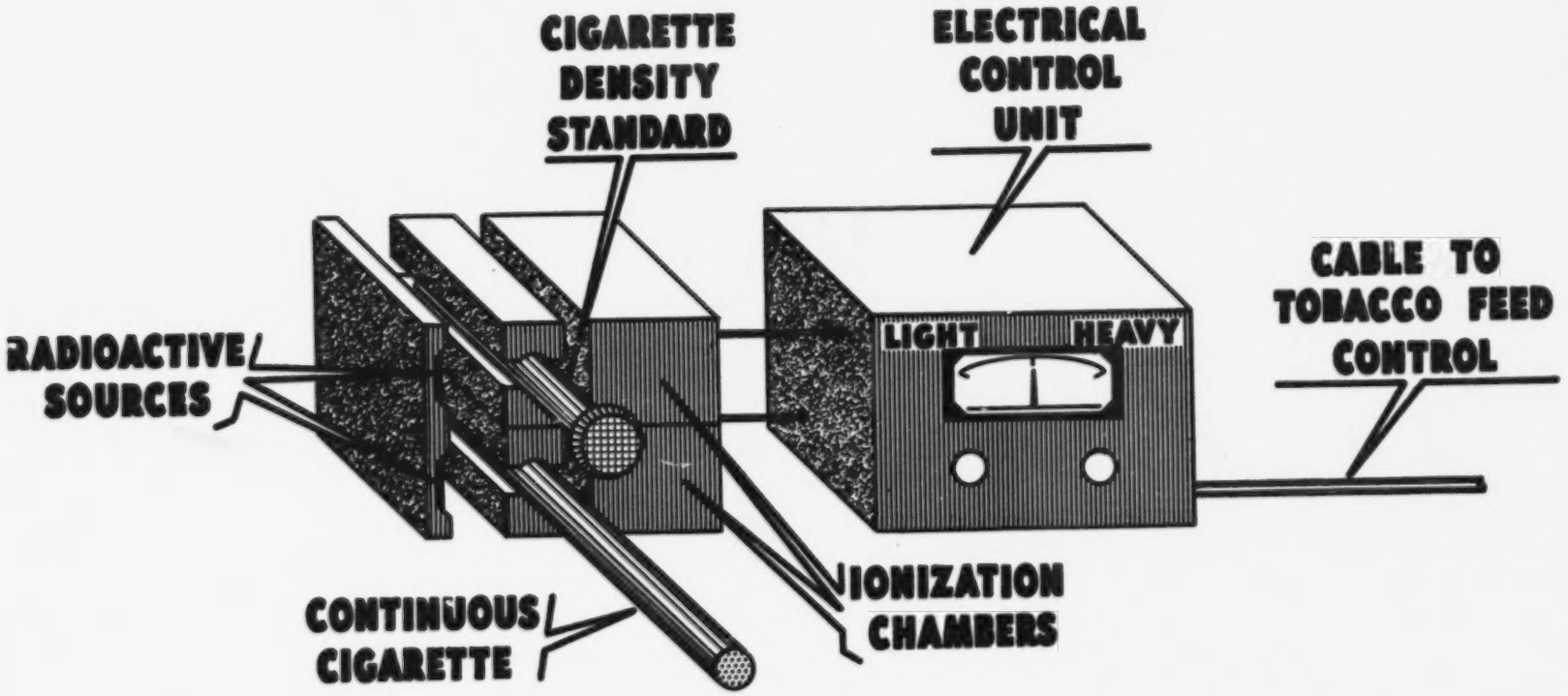
ORIGINAL DRAWING PRESSED AGAINST PHOTOGRAPHIC PAPER TO MAKE COPIES

ADVANTAGES:

1—PRODUCES FINELY DETAILED COPIES
2—TRUER THAN PHOTOGRAPHIC PRINT
3—LESS COMPLICATED EQUIPMENT
4—MORE PRECISE AND CHEAPER THAN LITHOGRAPH

USAEC-ID-224A

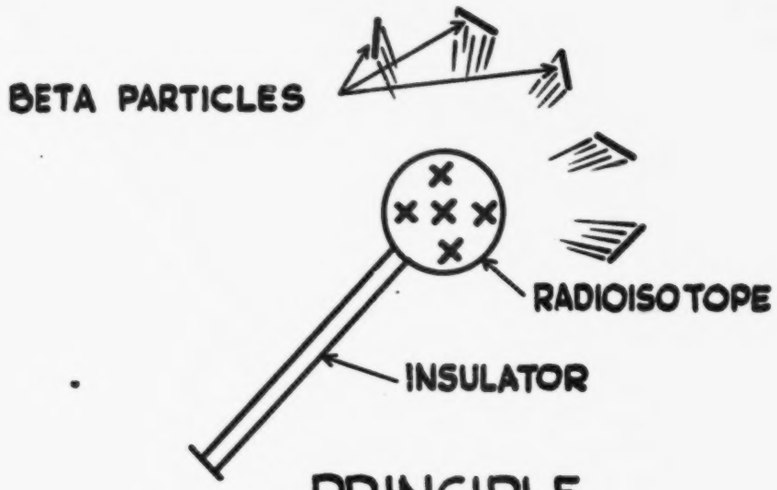
GAUGING CIGARETTE FIRMNESS
WITH RADIOISOTOPES



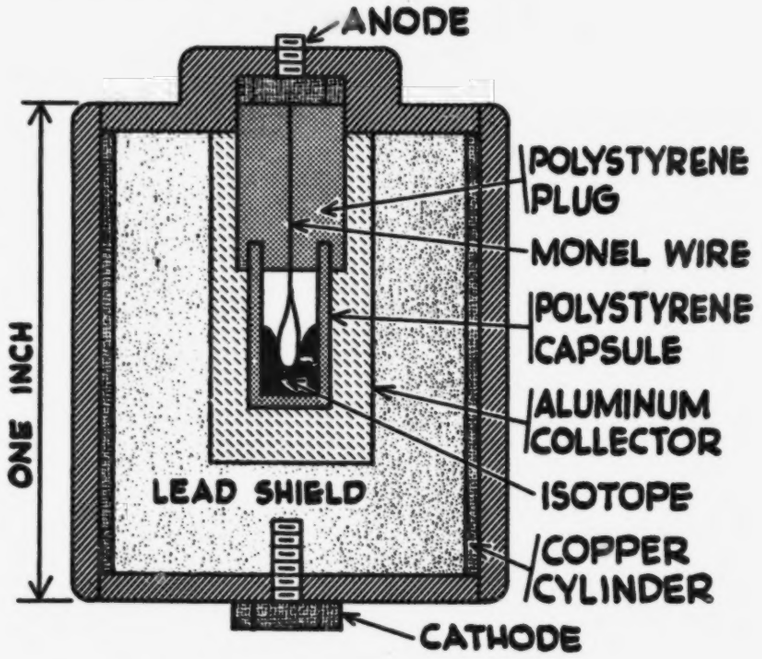
ADVANTAGES: 1-MORE UNIFORM FIRMNESS
2-SAVES TOBACCO
3-ELIMINATES MANUAL CONTROL

USAEC-ID-226A

Voltage Production AN INDUSTRIAL USE OF RADIOISOTOPES



PRINCIPLE



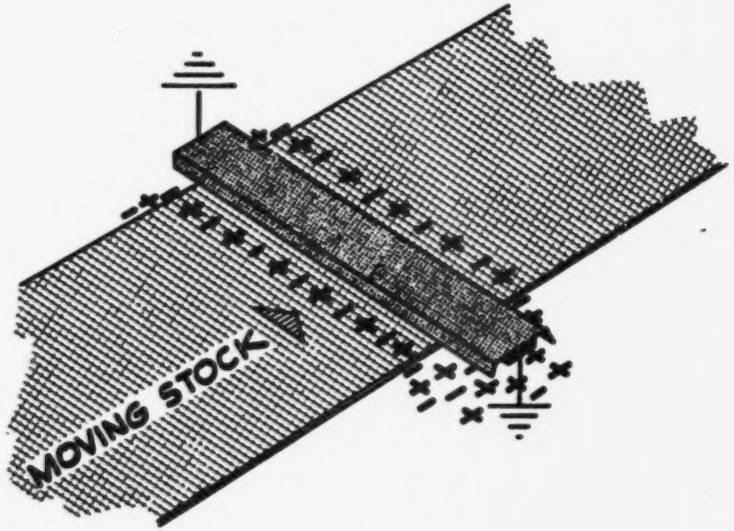
CHARACTERISTICS:

1 - MAXIMUM VOLTAGE UP TO 7kv
2 - 33% EFFICIENT
3 - 40$\mu\mu a$ AT ZERO VOLTAGE FOR 10mc Sr90
4 - LONG USEFUL LIFE UNDER EXTREME CONDITIONS
5 - SMALL - LIGHT - INEXPENSIVE

USAEC-ID-268A

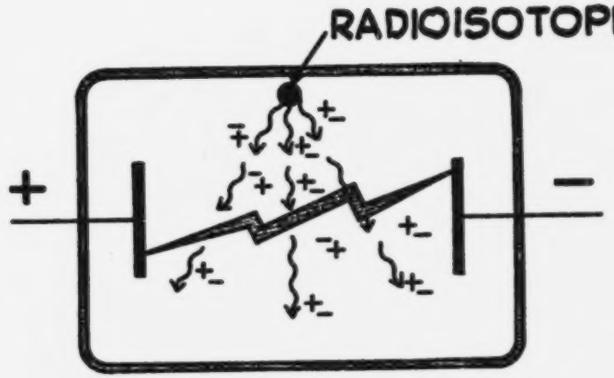
Ionization

INDUSTRIAL USE OF RADIOISOTOPES



STATIC ELIMINATOR

RADIATION PRE-IONIZES AIR PROVIDING EXIT PATH FOR STATIC



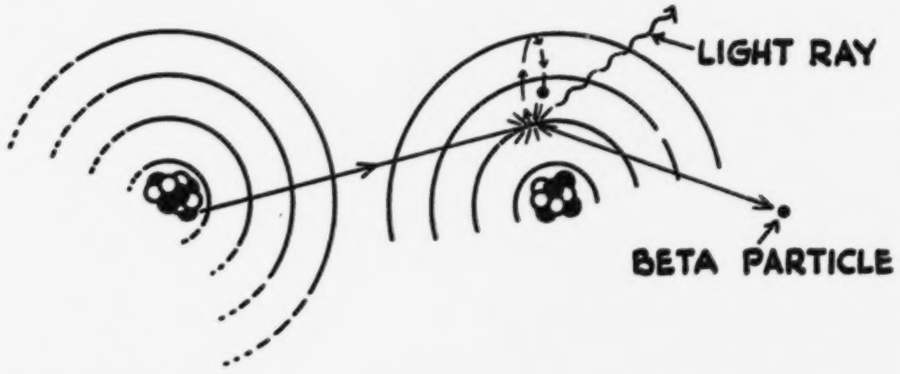
ELECTRON TUBE

RADIATION PARTIALLY PRE-IONIZES GAS GIVING DEPENDABLE FIRING CHARACTERISTICS

USAEC-ID-269A

Luminescence
AN
INDUSTRIAL USE OF RADIOISOTOPES

ONE MECHANISM



RADIOISOTOPE ACTIVATED MARKERS

BETA SOURCES CAUSE LESS PHOSPHOR DETERIORATION THAN ALPHA — HAVE LONGER USEFUL LIFE AND LOWER EXTERNAL RADIATION LEVEL — MULTIPLE COMBINATIONS ARE POSSIBLE.

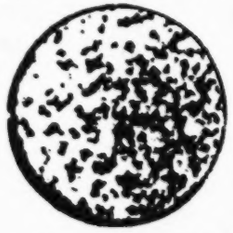
USAEC·ID·270A

Cold Sterilization

AN

INDUSTRIAL USE OF RADIOISOTOPES

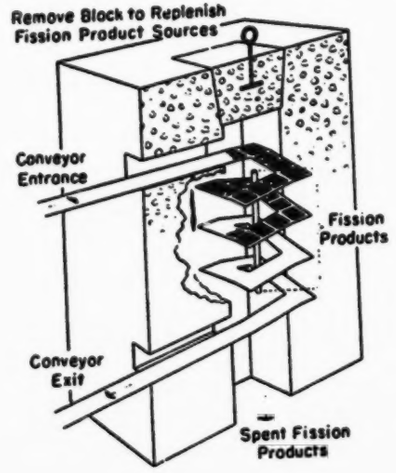
EFFECT OF RADIATION
ON MICROORGANISMS
(ASPERGILLUS NIGER)



NO RADIATION
(MOLD COUNT = 45,000,000)

260,000 REP
(MOLD COUNT = 0)

STERILIZATION UNIT

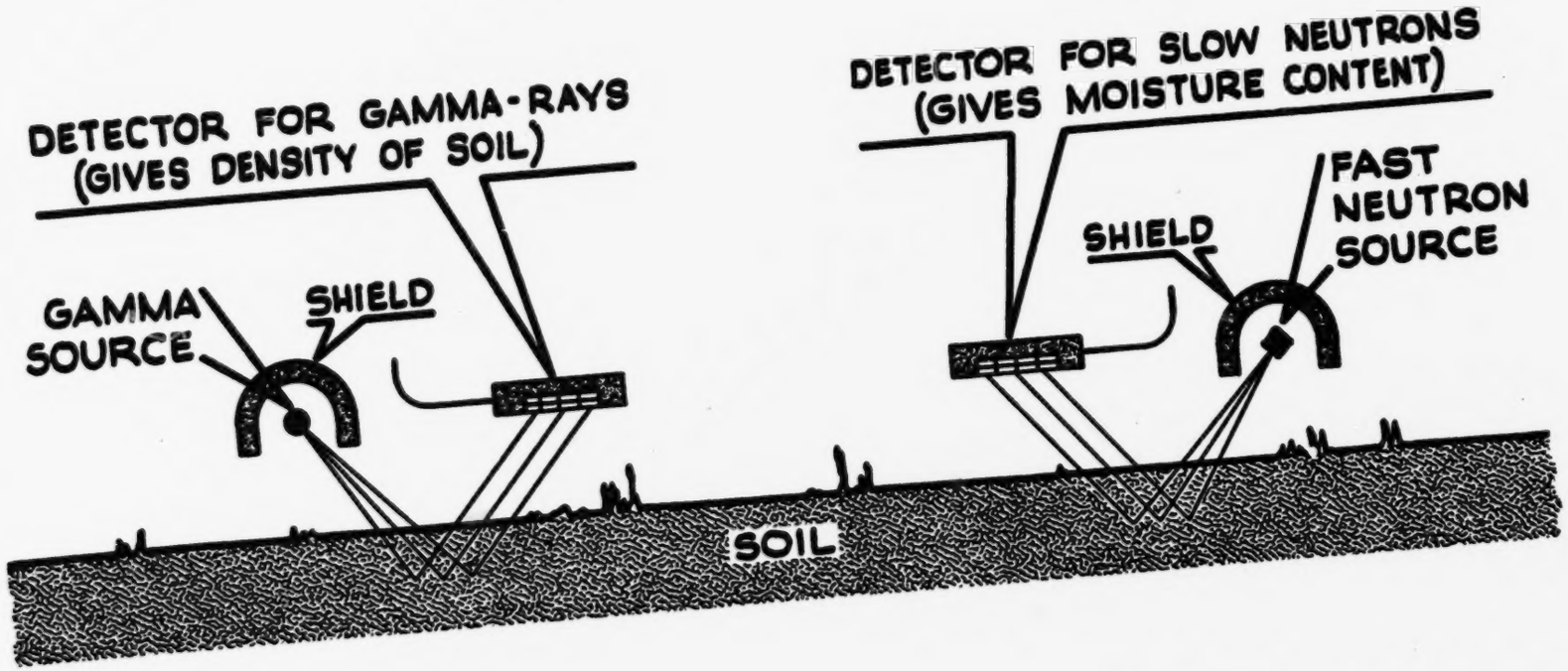


ATOMIC RADIATION HAS BEEN USED TO PRESERVE DRUGS — FOODS — KILL INSECT LARVAE IN PACKAGED PRODUCTS — CONTROL REPRODUCTION OF LIVESTOCK PESTS.

USAEC-ID-271A

Density and Moisture in Soil

AN INDUSTRIAL USE OF RADIOISOTOPES IN ROAD BUILDING



1- DATA OBTAINED WITHOUT MOVING SOIL
2- GAMMA-RAY DETECTOR MEASURES DENSITY
3- SLOW NEUTRON DETECTOR SHOWS MOISTURE

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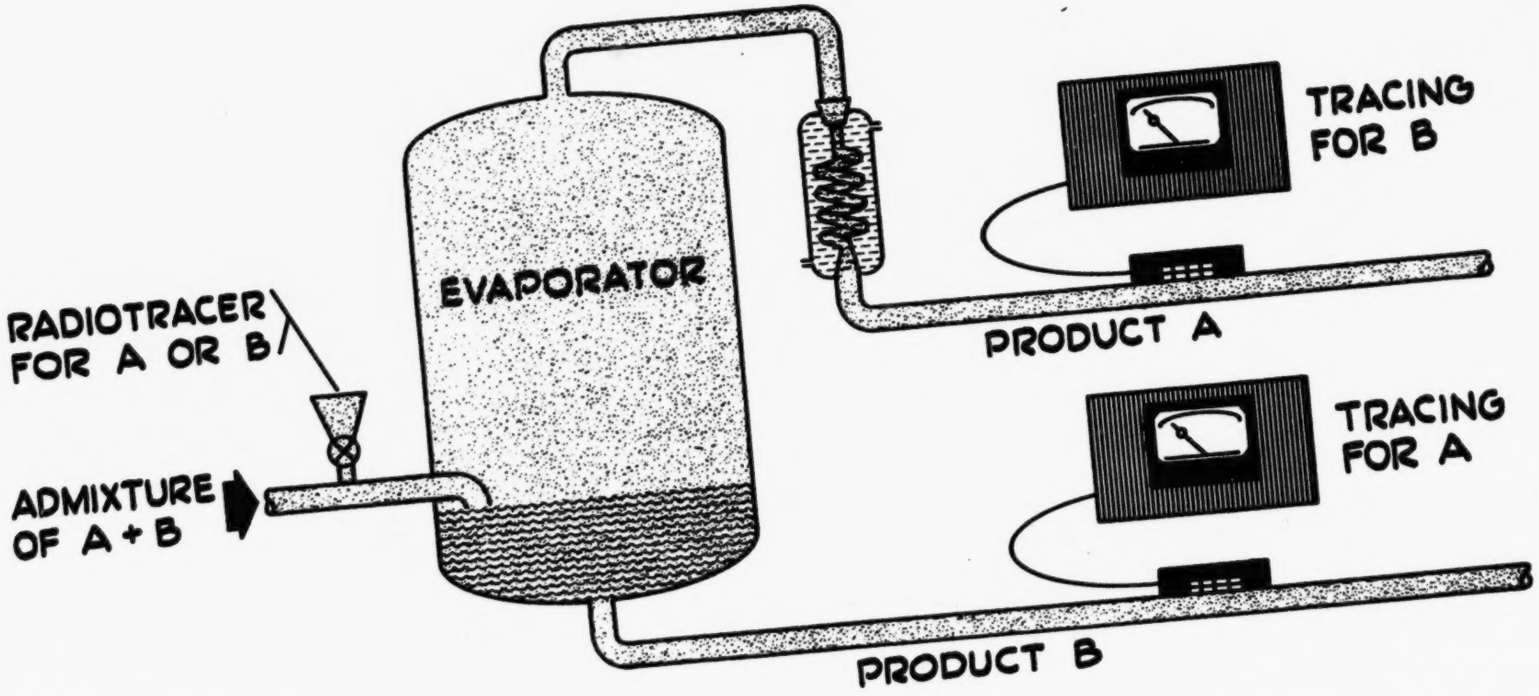
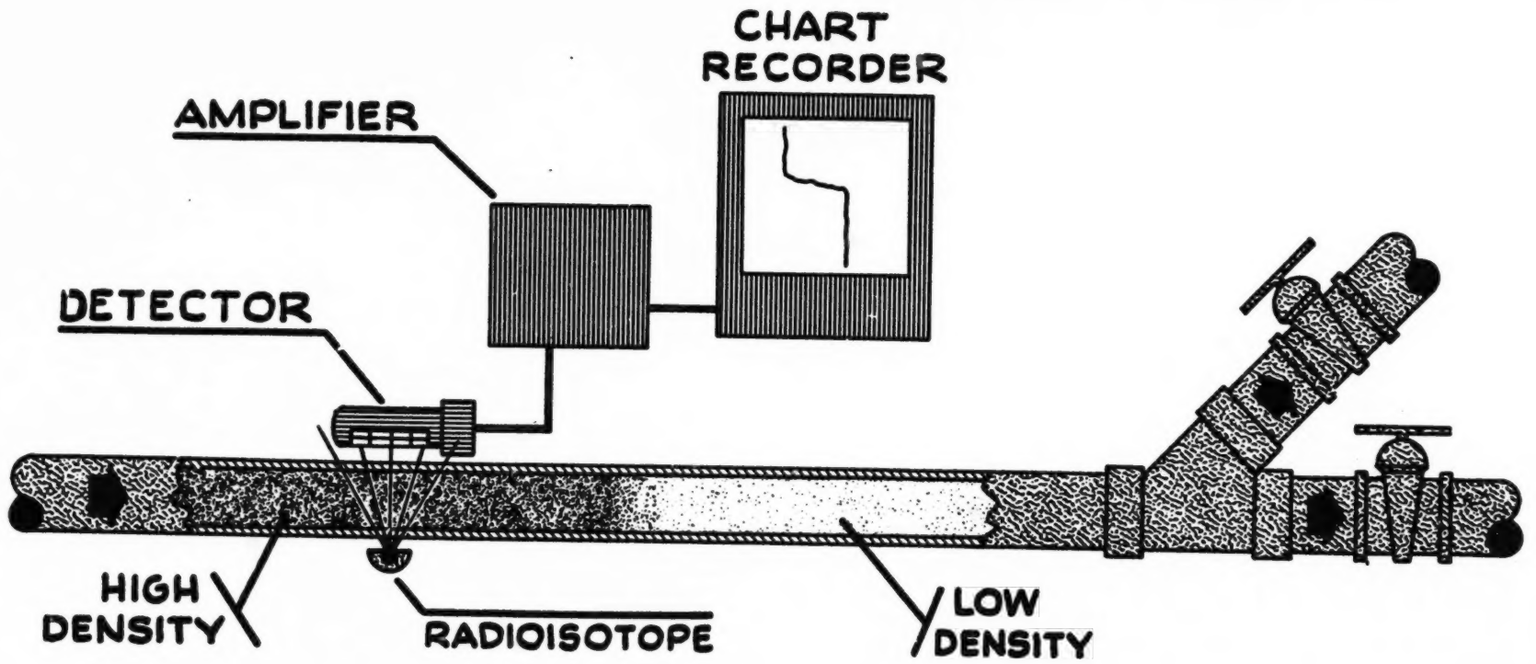
Measuring Efficiency of Separation USING RADIOACTIVE TRACER



QUANTITATIVE MEASUREMENTS WHEN CALIBRATED WITH STANDARD SAMPLES.

USAEC-ID-337A

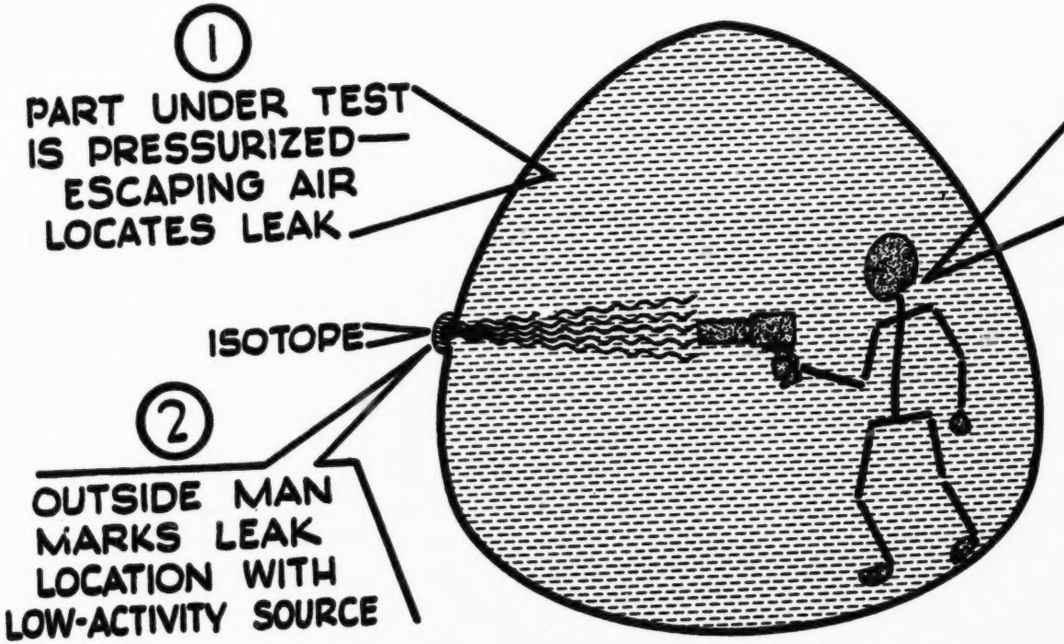
Detection of Interfaces IN PIPE-LINE FLOW (DENSITY GAGE)



- PERMITS SEPARATION OF LIQUIDS WITH MINIMUM OF LOSS
- METHOD QUICK AND REQUIRES NO SAMPLING

USAEC-ID-307A

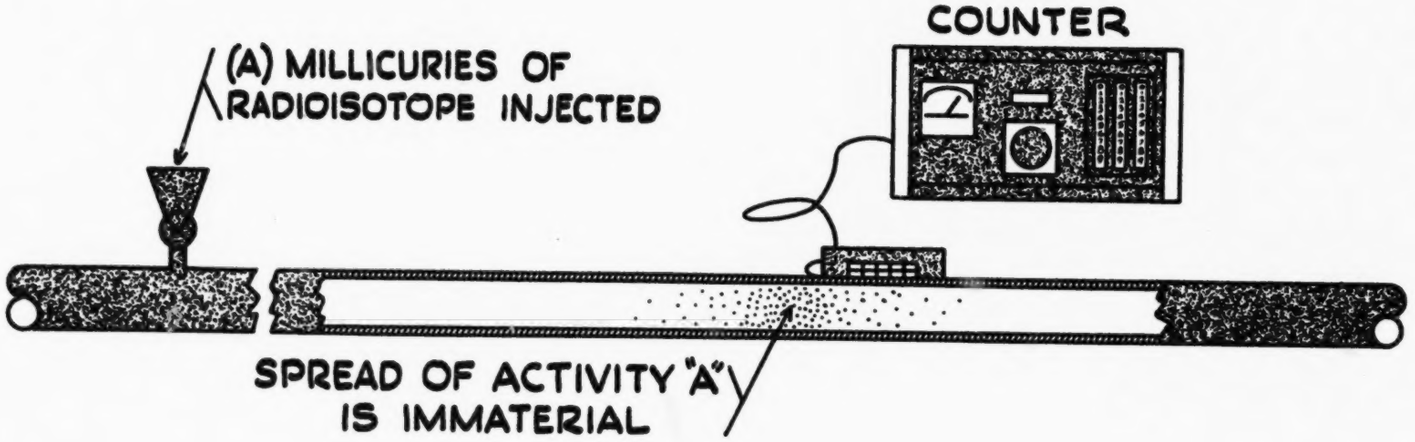
Isotope Marks Leak Location
IN
PRESSURE TESTING METHOD



..NEW SYSTEM SAVES 25% TIME AND COST.
..OLD SYSTEM REQUIRED TWO-MAN COMMUNICATIONS VIA HEAD-SET TO 'PIN-POINT" LEAK.

USAEC-ID-309A

Measuring Flow Rate by Integrated Count
USING
RADIOISOTOPE TRACER



COUNTING RATE DEPENDS ON CONCENTRATION

COUNTS/SEC = CONSTANT × MC/GALLON

TOTAL COUNT DEPENDS ON TIME OF PASSAGE

COUNTS = CONSTANT × SEC × MC/GALLON

THEREFORE, FLOW RATE IS GIVEN BY TOTAL COUNT

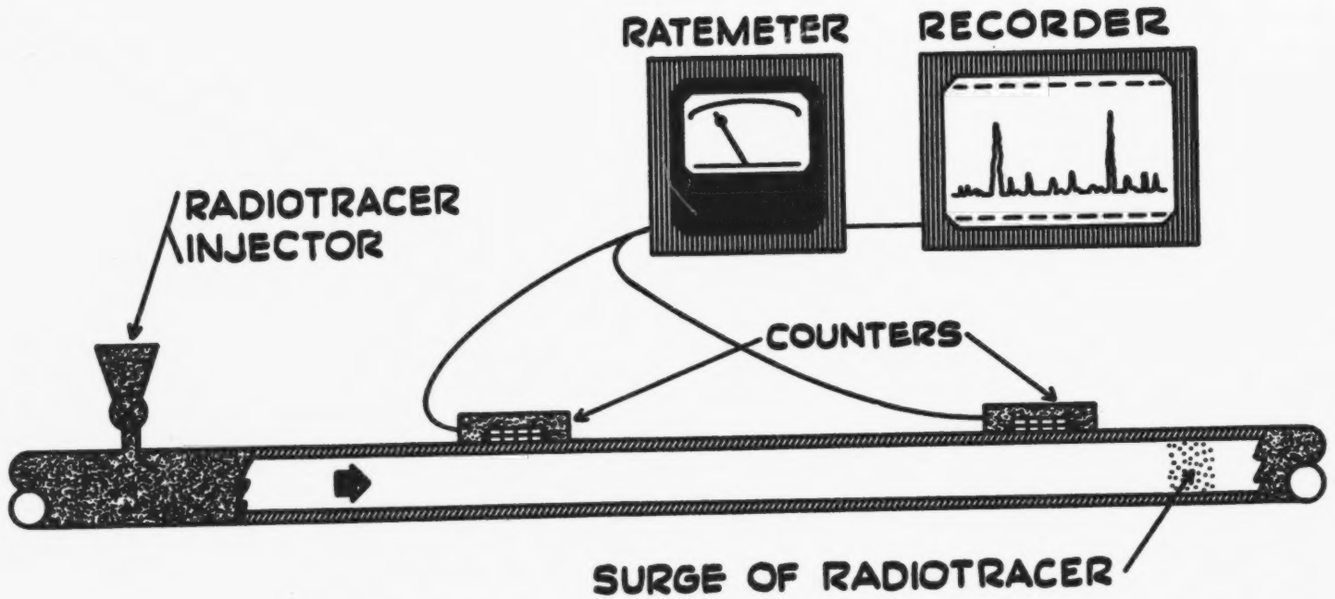
GAL/SEC = CONSTANT × "A" × 1/COUNTS

USAEC-ID-335A

Determining Flow Rate by Peak Timing

USING

RADIOACTIVE TRACER



.. PIPE CAPACITY BETWEEN COUNTERS IS V GALLONS

.. TIME BETWEEN COUNTER PESPONSES IS T MINUTES

FLOW RATE = V/T

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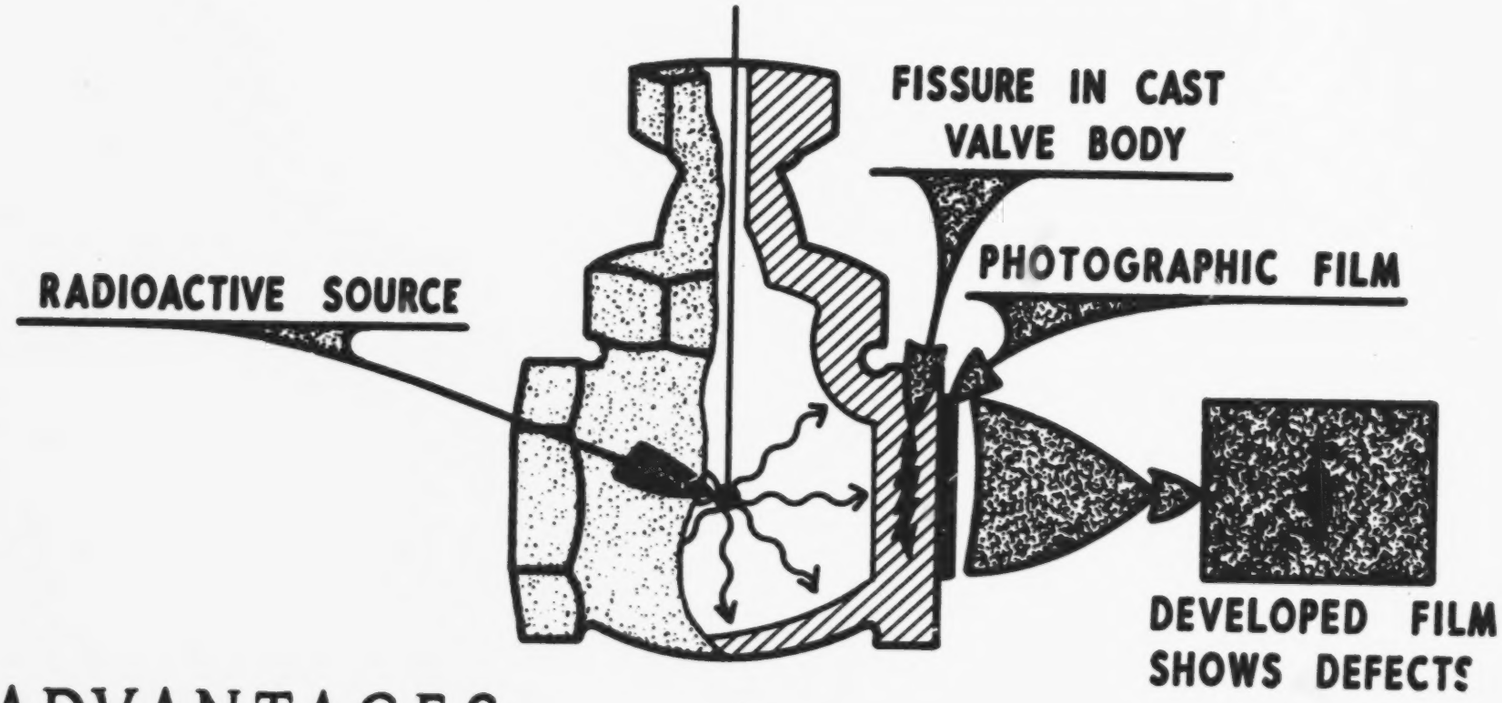
RADIOACTIVE COBALT - Co 60

FOR RADIOGRAPHY TESTING



ADVANTAGES:

1 - VERSATILE AND RELIABLE INSPECTION
2 - INSPECTION MADE WITHOUT DISMANTLING
3 - SOURCES OF DESIRED SHAPE AND SIZE
4 - VERY HIGH ACTIVITY SOURCES AVAILABLE AT LOW COST

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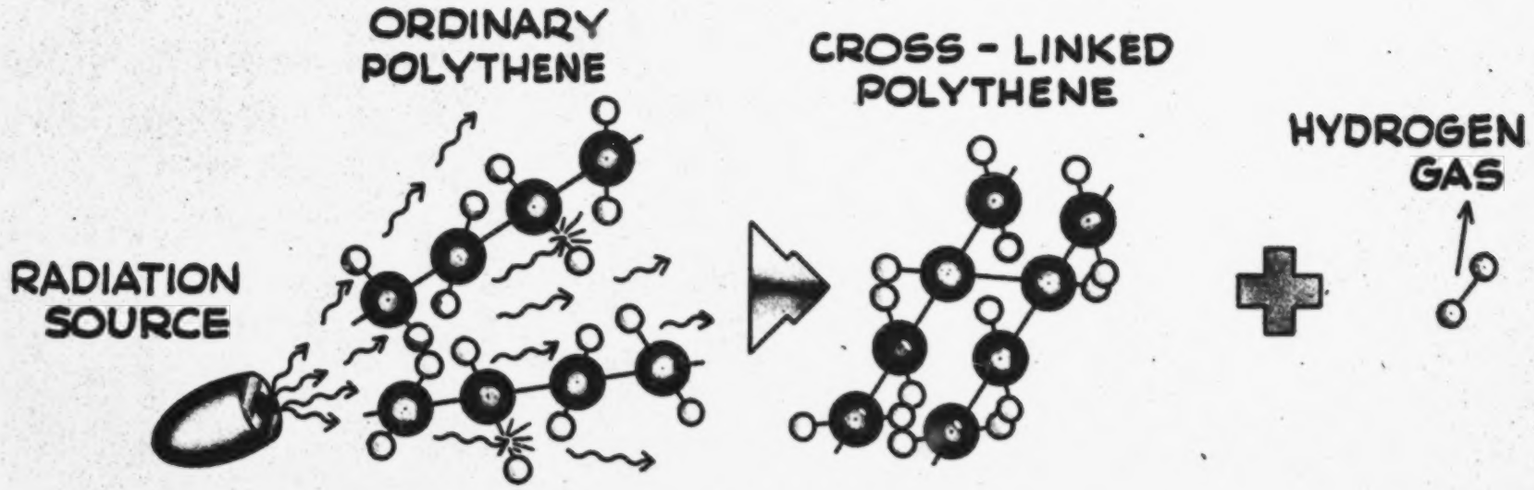
USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

Activation of Chemical Reactions
AN INDUSTRIAL USE OF RADIOISOTOPES



ADVANTAGES:

1 - CROSS-LINKED POLYTHENE IS:
- A - MORE HEAT RESISTANT
- B - MORE ELASTIC
- C - LESS SOLUBLE

2 - REQUIRES NO HEAT OR ADDITION OF FOREIGN ATOMS

3 - DEGREE OF CROSS-LINKING CAN BE CAREFULLY CONTROLLED

4 - MANY NEW PLASTICS CAN BE SYNTHESIZED

USAEC-ID-267A

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U. S. Atomic Energy Commission
Division of Technical Information Extension
Educational Materials Section
P. O. Box 62
Oak Ridge, Tennessee 37831

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